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PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

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(INSTITUTED 1852.)

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The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

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PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

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MINUTES OF MEETINGS.

OF THE SOCIETY.

January 7th, 1903.—The meeting was called to order at 8.45 P. M., Henry B. Seaman, Director, in the chair; Charles Warren Hunt, Secretary; and present, also, 87 members and 14 guests.

The minutes of the meetings of December 3d and 17th, 1902, were approved as printed in the *Proceedings* for December, 1902.

The discussion on the topic "The Sanitary Disposal of Municipal Refuse" was continued by Messrs. George A. Soper, Theodore Horton, W. J. Baldwin, Charles B. Ball, M. N. Baker, H. de B. Parsons and Rudolph Hering.

Ballots were canvassed and the following candidates declared elected:

As Members.

Thomas Hooker Loomis, Steubenville, Ohio.
William Martin, Bellevue, Pa.
John Colwell Neale, Pittsburg, Pa.

As Associate Members.

Lewis Eugene Ashbaugh, Ames, Iowa.
William Durward Connor, New London, Conn.
William Hastings Ferguson, Denver, Colo.
George Sherman Frost, New York City.
Charles Romney Hall, Portland, Me.
Austin Curtin Harper, Norfolk, Va.
Frederick William Schwiers, New York City.
John Eaton Shepardson, New York City.
Samuel Payson Waldron, East Berlin, Conn.
Ralph Norman Wheeler, New York City.

The Secretary announced the election of the following candidates by the Board of Direction on January 6th, 1903.

As Juniors.

Richard Erwin Dougherty, New York City.
William Dollison Faucette, Savannah, Ga.
Max Feldman, New York City.
Langdon Pearse, Roxbury, Mass.
William Edward Wilson, Detroit, Mich.

Adjourned.

January 21st, 1903.—The minutes of this, the Annual Meeting, will be printed in the *Proceedings* for February, 1903.

OF THE BOARD OF DIRECTION.

(Abstract.)

January 6th, 1903.—8.35 P. M.—Director O'Rourke in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Briggs, Croes, Jackson, Knap, Pegram, Seaman and Wilgus.

The cases of members in arrears for dues were considered and acted upon.

Upon the recommendation of the Finance Committee, it was decided to pay Ten Thousand Dollars on January 15th, 1903, on account of the principal of the mortgage held by the Mutual Life Insurance Company on the Society House.

A draft of the report to the Board of Direction was presented, by the Special Committee appointed for that purpose, and adopted.

The report of the Committee to recommend the award of prizes for the year ending with the *Transactions*, July, 1902, was received, and the prizes awarded, in accordance with the recommendations of that report, as follows:

The Norman Medal to Paper No. 911, "Experiments at Detroit, Michigan, on the Effect of Curvature upon the Flow of Water in Pipes" by Gardner S. Williams, M. Am. Soc. C. E., Clarence W. Hubbell, Assoc. M. Am. Soc. C. E., and George H. Fenkell, Jun. Am. Soc. C. E.

The Thomas Fitch Rowland Prize to Paper No. 910, "Description of Coos Bay, Oregon, and the Improvement of Its Entrance by the Government," by William W. Harts, M. Am. Soc. C. E.

The following resignations were accepted: S. E. Barney, Assoc. M., Frederic V. Pitney, Assoc. M., Henry H. Shepard, Assoc. M., R. C. McKinney, Assoc., Mark Fargusson, Jun., Myron H. Lewis, Jun., George E. Nostrand, Jun., George R. Wadsworth, Jun.

Applications were considered and other routine business transacted.

Five candidates for Junior were elected.*

Adjourned.

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* See page 2.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, February 4th, 1903.—8.31 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and there will be an informal discussion on "The Preservation of Materials of Construction." It is not intended to confine this discussion to any particular material or method, but to invite exchange of opinion, based on experience, of practical methods of securing permanence in engineering structures of all types. Several members have already agreed to take part, and it is hoped that others will come prepared to speak, or will send written communications on the subject.

Wednesday, February 18th, 1903.—8.30 P. M.—At this meeting a paper by George S. Morison, Past-President, Am. Soc. C. E., entitled "The Panama Canal," will be presented for discussion. This paper is printed in this number of *Proceedings.*

Wednesday, March 4th, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper by M. H. Gerry, Jr., Assoc. M. Am. Soc. C. E., entitled "A High-Voltage Power Transmission," will be presented for discussion. This paper is printed in this number of *Proceedings.*

ANNUAL CONVENTION OF 1903.

The Thirty-fifth Annual Convention of the Society will be held at Asheville, N. C., during the week beginning June 8th, 1903.

ANNUAL REPORT OF THE BOARD OF DIRECTION FOR THE YEAR ENDING DECEMBER 31st, 1902.

PRESENTED AT THE ANNUAL MEETING, JANUARY 21st, 1903.

The Board of Direction, in compliance with the Constitution of the Society, presents its report for the year ending December 31st, 1902.

MEMBERSHIP.

The changes in membership are shown in the following table:

Grade.	Jan. 1st, 1902.			Jan. 1st, 1903.			Losses.				Additions.		Totals.	
	Resident.	Non-Resident.	Total.	Resident.	Non-Resident.	Total.	Transfer.	Resignation.	Dropped.	Death.	Transfer.	Election.	Loss.	Gain.
Honorary Members	1	9	10	1	8	9	..	..	..	1	....	....	1	....
Corresponding Members	....	2	2	....	2	2	..	..	..	..	....	....	....	....
Members	286	1 222	1 508	312	1 263	1 575	..	1	2	24	*28	§66	27	94
Associate Members	161	451	612	192	522	714	25	5	2	8	†35	‖102	35	137
Associates	38	73	111	43	76	119	2	1	..	3	‡2	12	6	14
Juniors	101	150	251	107	154	261	38	6	14	..	....	68	58	68
Fellows	9	25	34	10	23	33	..	..	..	1	....	....	1	....
Totals	596	1 932	2 528	665	2 048	2 713	65	13	18	32	65	248	128	313

* 25 Associate Members and 3 Juniors.
† 2 Associates and 33 Juniors.
‡ 2 Juniors.
§ 1 Reinstatement.
‖ 1 Reinstatement.

It will be seen that the net increase during the year was 185.

In the report of the Board for 1902, statistics of the yearly growth of the Society for thirty-two years were given, and it was pointed out that the rate of increase for the last few years was apparently not due to temporary conditions. The result of this year seems to emphasize this, the figures of the increase for the past four years being as follows:

1899—Net increase in total membership	103
1900 " " " " "	138
1901 " " " " "	191
1902 " " " " "	185
Total for the past four years	617
Average yearly increase for the past four years	154
Average yearly increase from 1869 to 1898, inclusive	62

The total number of applications received during the year was 362.

Action taken by the Board has been as follows:

Passed to ballot as Members	109
Passed to ballot as Associate Members	140
Elected Associates	14
Elected Juniors	65
Total	328
Applications awaiting action	90

The losses by death reported during the year number 32. They are as follows:

Honorary Member: William Hasell Wilson.

Members: Edward Josiah Blake, Charles Edward Henry Campbell, Lorenzo Russell Clapp, Emilio Del Monte, William Durfee Gelette, Edmund Phillips Hannaford, Charles Fletcher Hillman, Arthur Stanley Hobby, Milton Grosvenor Howe, John Butler Johnson, Moritz Lassig, Charles Hazlehurst Latrobe, William Shattuck Lincoln, George Henry Mendell, James Ellison Mills, Henry Mitchell, Nathaniel Edwards Russell, Ira Alexander Shaler, Martinius Stixrud, Robert Henry Temple, William Van Slooten, Robert Atwell Way, Oscar F. Whitford, Joseph Miller Wilson.

Associate Members: Henry Lawrence Cleverdon, Reginald McKean, Kenneth Oake Plummer Reinholdt.

Associates: John Woodbridge Davis, Charles Edward Hamlin, Peter Milne.

Fellow: Nathaniel Cheney.

LIBRARY.

The accessions to the Library during the year are shown in the following table:

Accessions During the Year 1902.

	Bound Volumes.	Unbound Volumes.	Specifications.	Maps, Photographs and Drawings.	Total.
Donations—					
In answer to special requests	272	1 153	....	1	1 426
From publishers	47	14	....	...	61
Eng. News Pub. Co.	24	148	25	...	197
In regular course	214	1 047	3 070	306	4 637
Exchange of duplicates	322	368	....	...	690
By purchase	237	238	....	...	475
Total	1 116	2 968	3 095	307	7 486

In addition to the above, there have been received 489 duplicates, and 234 separate numbers to complete files of periodicals, neither of which can appear as accessions.

A comparison with the corresponding figures for last year shows that the growth of the Library in 1902 has exceeded that of 1901 (which was regarded as phenomenal) by 1 459 accessions.

The Library now contains:

Bound volumes	11 330
Unbound volumes	27 609
Specifications	5 658
Maps, photographs and drawings	3 000
Total	47 597

The total number of titles in the Library is 19 178.

During the year, 890 volumes have been bound, and 55 bound volumes which were duplicates were received and have replaced previously unbound volumes.

The following amounts have been expended upon the Library during the year:

Purchase of books, 475 volumes	$1 224.87
Express charges, etc	99.90
Binding 890 volumes	931.25
Fixtures and supplies	207.29
Total	$2 463.31

The value of the accessions to the Library during the year is as follows, each accession having been valued separately, as received:

7 011 Donations and exchanges (estimated value)	$2 822.41
475 Volumes purchased (cost)	1 224.87
Binding 890 volumes	931.25
	$4 978.53

Owing to the rapid increase of the Library, and the accession of many new books, by purchase and otherwise, it has been decided to publish a second volume of the classified Catalogue, the first volume of which was published in 1900. This volume is now nearly all in type, and it is expected will be issued to all members in about a month.

For the first 45 years of the life of the Society the total number of accessions to the Library was 30 847, an average yearly addition of 685 volumes. About the close of 1897 the Library was moved into the new House. Since that time the average yearly addition has been 3 350 volumes, the total, as stated above, being now 47 597.

By the terms of the will of the late Herbert Steward, Assoc. Am. Soc. C. E. (who died March 4th, 1899), the Society has received, during the year, $1 940, and the Board has accepted this bequest under the terms of Mr. Steward's will, which were as follows:

> "I give and bequeath to the American Society of Civil Engineers the sum of two thousand dollars, to be known as the Herbert Steward Library Fund. The fund shall be invested and utilized as the Board of Direction of said Society may elect, provided it shall secure a yearly income; which income shall be entirely expended each year for the purchase of books, maps, or apparatus suitable for the Library of said Society, or for the purpose of promulgating engineering information. I also give to said Society such technical books from my library as may be selected by the Secretary of the Society."

A gift of £10 was also received during the year from *Sir* Benjamin Baker, Hon. M. Am. Soc. C. E., for library purposes.

PUBLICATIONS.

During the year the usual ten numbers of *Proceedings* have appeared, and three volumes of *Transactions*, instead of the usual two, have been published.

In the *Proceedings*, the list of references to current engineering literature has covered 51 pages, containing 2 614 classified references to 62 periodicals.

The demand for publications has been much greater than usual, subscriptions and sales during the year amounting to $3 231.16.

The stock of the various publications of the Society, kept on hand for the convenience of members and others, now amounts to 119 850 copies, the actual cost of which to the Society has been $13 904.42.

More than 3 200 volumes of *Transactions* have been bound, during the year, for members and others, in the standard half-morocco or cloth bindings.

Summary of Publications for 1902.

	Number Issued.	Total Edition of Each.	Number of Pages.	Plates.	Cuts.
*Transactions**	3	2 800 2 900 3 100	1 434	52	327
*Proceedings**	10	3 000	1 266	40	141
Constitution and List of Members	1	3 200	237	....	....
Advertisements	10	3 000	108	....	....
Totals	....	......	3 045	92	468

* Includes Indexes and Tables of Contents.

The cost of publications has been:

For Paper, Printing, Binding, etc., *Transactions* and *Proceedings*		$8 211.14
For Plates and Cuts		957.56
For Boxes, Mailing Lists, Copyright and Sundry Expenses		231.50
For Commission on Advertisements		265.09
For 6 575 copies of Memoirs and Papers		734.61
For List of Members		909.33
Total		$11 309.23
Deduct amount received for advertisements	$1 807.50	
Deduct amount received for sale of publications	3 231.76	
		5 039.26
Net cost of Publications for 1902		$6 269.97

Since publications were begun by the Society, 31 years ago, there have been published 49 volumes of *Transactions*, 28 volumes of *Proceedings* and 33 miscellaneous separate publications, consisting of Indexes, Catalogues, Lists of Members, etc. The total number of pages in these publications has been 42 099, an average yearly output of 1 358 pages.

Beginning with 1896, the system of publication was changed, and since that time *Proceedings* and *Transactions* have been issued separately.

For the 24 years, 1872-1895 (inclusive), there were issued 22 799 pages, a yearly average of 950 pages, and for the past 7 years the total issue has been 19 300 pages, an average of 2 757 pages per year.

MEETINGS.

During the year 25 meetings have been held, as follows: At the Annual Meeting, 2; at the Annual Convention, 6; regular semi-monthly meetings, 17.

At these meetings there were presented 18 formal papers, 4 of which were illustrated with lantern slides; 7 topics for informal discussion, one of which was illustrated with lantern slides; and 8 illustrated lectures.

The Thirty-fourth Annual Convention was held at the Willard Hotel, Washington, D. C. There were registered at this Convention 343 members of the Society, in all grades, accompanied by 377 members of their families, and other guests. This was the most largely attended Convention of the Society ever held.

MEDALS AND PRIZES.

For the year ending with the month of July, 1901, Prizes were awarded, as follows:

The Thomas Fitch Rowland Prize, to L. G. Montony, Assoc. M. Am. Soc. C. E., for his paper entitled "The Ninety-Sixth Street Power Station of the Metropolitan Street Railway Company, of New York City."

The Collingwood Prize for Juniors, to F. A. Kummer, Jun. Am. Soc. C. E., for his paper entitled "A Proposed Method for the Preservation of Timber."

No award of the Normal Medal was made.

FINANCES.

An examination of the Secretary's statement of receipts and disbursements, and of the general balance sheet which accompanies it, will show the financial condition of the Society. During the year the sum of $1 940 has been received from the Executors of the estate of the late Herbert Steward, Assoc. Am. Soc. C. E., this sum to be invested and the yearly proceeds to be used in the purchase of books, maps, or apparatus suitable for the library, or for the purpose of promulgating engineering information.

When, in 1895, the project for building a new house was under consideration, the total assets of the Society (omitting the estimated value of the Library, and of publications in stock) were about $65 000. Making no allowance for increase in the value of the present property since it was purchased, the total assets now are about $167 000.

In the report of the Board for the year 1898, it is stated that "the permanent loan has been fixed at $85 000, which loan has been secured at a rate of 4½ per cent." The payment, on January 15th, 1903, of $10 000 on the principal of the mortgage, which has been authorized by the Board, will reduce the debt to $55 000, which is now carried at 4% interest. In other words, $30 000 has been paid off in four years.

The reports of the Secretary and the Treasurer are appended.

By order of the Board of Direction,

CHAS. WARREN HUNT,
Secretary.

NEW YORK, January 6th, 1903.

GENERAL BALANCE SHEET, DECEMBER 31st, 1902.

Accompanying Report of the Secretary.

Assets.			Liabilities.	
Building and Lot (cost)		$191 730.26	Dues for 1903, paid in advance	$12 127.23
Furniture (cost)		15 664.30	Mortgage Debt	65 000.00
Publications on hand; inventoried value		13 904.42	Funds invested in Society House and Lot, and Library	223 150.82
Library:				
Cash expended for Books, etc.	$7 824.88			
Estimated Value of Donations	40 600.73	48 425.61		
Due from Members	$3 456.26			
" " Non-Members, for Publications	244.81			
" for Advertising	555.00			
		4 256.07		
Cash		26 297 39		
		$300 278.05		$300 278.05

New York, 19th January, 1903.—We have examined the books and accounts of the American Society of Civil Engineers, and certify that the foregoing Balance Sheet is in accordance therewith, as of 31st December, 1902; and, in our opinion, correctly states the condition of the Society's affairs as shewn by the books at that date.

Menzies, Robertson & Co.,
Chartered Accountants.

REPORT OF THE SECRETARY, FOR THE

To the Board of Direction of the

Gentlemen,—I have the honor to present a statement of Re-
December 31st, 1902. There is also presented a general balance sheet
New York, January 6th, 1903.

Receipts.

Balance on hand December 31st, 1902, in Bank and Trust Company and in hands of the Treasurer		$15 993.31
Entrance Fees	$6 025.00	
Current Dues	30 786.47	
Past Dues	1 256.88	
Advance dues	12 127.23	
Certificates of Membership	197.47	
Badges	1 213.00	
Sales of Publications	3 231.76	
Advertisements	1 807.50	
Interest	307.35	
Compounding Dues	250.00	
Library	50.75	
Annual Meeting	223.00	
Binding	2 896.87	
Miscellaneous	156.57	
Herbert Steward Library Fund	1 940.00	
Caretaking	28.00	
		62 497.85
		$78 491.16

YEAR ENDING DECEMBER 31st, 1902.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

ceipts and Disbursements for the fiscal year of the Society, ending showing the condition of the affairs of the Society.

Respectfully submitted,

CHAS. WARREN HUNT,
Secretary.

DISBURSEMENTS.

Salaries of Officers	$8 199.97	
Clerical Help	8 759.34	
Caretaking	1 852.23	
Publications	11 044.14	
Postage	3 354.08	
General Printing and Stationery	1 747.84	
Badges	975.20	
Certificates of Membership	117.80	
Binding	2 033.11	
Library	2 459.56	
Maintenance of House	334.71	
Heat, Light and Water	1 068.79	
Betterments	29.48	
Furniture	360.34	
Annual Meeting	785.30	
Convention	434.50	
Prizes	111.00	
Advertising Commission	265.09	
Interest and Insurance	2 700.00	
Petty Expenses	182.29	
Society House Loan	5 000.00	
Current Business	357.95	
Refunds	21.05	
		$52 193.77
Balance on Hand December 31st, 1902:		
In Union Trust Company	$24 562.41	
In Garfield National Bank	749.98	
In hands of Treasurer	985.00	
		26 297.39
		$78 491.16

REPORT OF THE TREASURER.

In compliance with the provision of the Constitution, the Treasurer presents the following report for the year ending December 31st, 1902:

Balance on hand December 31st, 1901			$15 993.31
Receipts from current sources, January 1st to December 31st, 1902		$60 509.35	
Received from Herbert Steward Library Fund		1 940.00	
Received from Sir Benjamin Baker		48.50	
			62 497.85
Payment on audited vouchers for current business, January 1st to December 31st, 1902		$47 193.77	
Payment on principal of Bond and Mortgage		5 000.00	
Balance on hand December 31st, 1902:			
In Union Trust Company	$24 562.41		
In Garfield National Bank	749.98		
In hands of the Treasurer	985.00	26 297.39	
		$78 491.16	$78 491.16

Respectfully submitted,

JOSEPH M. KNAP,

Treasurer, Am. Soc. C. E.

New York, January 6th, 1903.

ACCESSIONS TO THE LIBRARY.

From December 10th, 1902, to January 13th, 1903.

DONATIONS.*

THE CIVIL ENGINEER'S POCKET-BOOK.

By John C. Trautwine. Revised by John C. Trautwine, Jr., and John C. Trautwine, 3d. Eighteenth Edition, Morocco, 7 x 4 ins., 1 079 pp., illus. New York, John Wiley & Sons, 1902. $5.00. (Donated by John C. Trautwine, Jr., and John C. Trautwine, 3d.)

The preface states that in preparation for the eighteenth edition, this book, the first edition of which appeared thirty years ago, has undergone a far more extensive revision than at any other time. More than 370 pages of new matter have been added, and the new edition is larger, by about 100 pages, than its recent predecessors. The articles on arithmetic are considerably extended by the addition of new matter relating to interest, annuities, depreciation, etc. The conversion tables contain the equivalents of both English and metric units, and each of these in terms of the other. The new article on the location of the meridian is much more complete than its predecessors, and a new table of azimuths of Polaris, corresponding to different hour-angles, has been added. Among the important changes in this edition are those in the articles on Statics, on Beams, and on Trusses. These have been almost entirely rewritten and completely modernized. Under Trusses, modern methods of construction are explained, and several modern roofs and bridges are described and illustrated. The Contents are: Mathematics; Natural Phenomena; Mechanics; Force in Rigid Bodies; Strength of Materials; Hydrostatics; Hydraulics; Constructions, etc.; Water Supply; Test and Well Boring; Rock Drills; Traction, Animal Power; Trusses; Suspension Bridges; Rivets and Riveting; Railroads; Materials. There is an index of forty-one pages.

ANCIENT AND MODERN ENGINEERING AND THE ISTHMIAN CANAL.

By William H. Burr, M. Am. Soc. C. E., M. Inst. C. E. Cloth, 9 x 6 ins., 15 + 473 pp., illus. New York, John Wiley & Sons, 1902. $3.50. Postage or Express, 27 cents additional.

This book is the outcome of a course of six lectures delivered at the Cooper Union in the City of New York, in February and March, 1902, under the auspices of Columbia University. These lectures have been expanded for the purposes of publication. The half-tone illustrations, with scarcely an exception, have been prepared from photographs of the actual subjects illustrated. All such illustrations in Parts V and VI, devoted to the Nicaragua and Panama Canal Routes, are made from photographs at the various locations by members of the force of the Isthmian Canal Commission. The parts are: Ancient Civil Engineering Works; Bridges; Water-Works for Cities and Towns; Some Features of Railroad Engineering; The Nicaragua Route for a Ship-Canal; The Panama Route for a Ship-Canal.

A TREATISE ON ROADS AND PAVEMENTS.

By Ira Osborn Baker, M. Am. Soc. C. E. Cloth, 9 x 6 ins., 8 + 655 pp., illus. New York, John Wiley & Sons, 1903. $5.00.

The author states in the preface that the object of this book is to give a discussion, from the point of view of an engineer, of the principles involved in the construction of country roads and city pavements. The attempt has been made to show that the science of road making and maintenance is based upon well-established elementary principles, and that the art depends upon correct reasoning from the principles rather than in attempting to follow rules or methods of construction. In some cases practical experience has not yet determined the best method of procedure, and in these cases the conflicting views with the reasons for each are fully stated. Considerable space has been given to the economics and location of country roads and to the construction and maintenance of earth roads. The remainder of the book, the portion that considers roads having permanently hard surfaces, is based chiefly upon American experience. The Contents are: Part I. Country Roads. Road Economics; Road Location; Earth Roads; Gravel Roads; Broken-Stone Roads; Miscellaneous Roads; Equestrian Roads and Horse-Race Roads. Part II. Street Pavements. Pavement Economics; Street Design; Street Drainage; Curbs and Gutters; Pavement Foundations; Asphalt Pavements; Brick Pavements; Cobble-Stone Pavement; Stone-Block Pavement; Wood-Block Pavements; Comparison of Pavements; Sidewalks; Bicycle Paths and Race Tracks. There is an index of nine pages.

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* Unless otherwise specified, books in this list have been donated to the Library by the Publisher.

POWER DISTRIBUTION FOR ELECTRIC RAILROADS.

By Louis Bell. Third Edition, Revised and Enlarged. Cloth, 9 x 6 ins., 7 + 303 pp., illus. New York, Street Railway Publishing Company, 1900. $2.50.

The preface states that this book is written in the hope that it may be of service to those whose daily work is concerned with the art of transportation, in which electrical traction is to-day so potent a factor. The author has endeavored to set forth the general principles of the distribution of electrical energy to moving motors, to describe the methods which experience has shown to be desirable in such work, and to point out the ways in which these principles and methods can be co-ordinated in every-day practice. For the most part, apparatus is too mutable to describe exhaustively, unless one is writing a history. The reader will therefore find little of such detail. The volume deals with principles and methods, and, consequently, the examples given in the first edition are, save in unimportant details, as typical of current practice in 1900 as they were in 1896. The chapter headings are: Fundamental Principles; The Return Circuit; Direct Feeding Systems; Special Methods of Distribution; Substations; Transmission of Power for Substations; Alternating Motors for Railway Work; Interurban and Cross Country Work; Fast and Heavy Railway Service.

COMBUSTIBLES INDUSTRIELS.

Houille, Pétrole, Lignite, Tourbe, Bois, Charbon de Bois, Agglomérés, Coke. Par Felix Colomer et Charles Lordier. Paper, 10 x 6¼ ins., 565 pp., illus. Paris, Vve. Ch. Dunod, 1903. 19 fr. 50.

For each of the above named fuels, one will find in this work information on its physical and chemical properties, its method of preparation, its use in the various furnaces for stationary boilers, locomotives or ships, its conditions of purchase, etc. The Contents are: Houille—Définition et classification de la houille; Essais et analyse de la houille; Sortage de la houille; Lavage de la houille; Définition industrielle et achat de la houille; Emploi de la houille dans les foyers; Foyers spéciaux; Pétrole—Propriétés et analyse du pétrole; Emplois du pétrole; Brûleurs à pétrole; Lignite, Tourbe, Bois, Charbon de Bois; Agglomérés—Généralités sur les agglomérés; Outillage des usines à agglomérés; Appareils de compression; Coke—Définition et emploi du coke; Théorie de la carbonisation; Fours à coke; Récupération des sous-produits; Installation et prix de revient d'une usine de carbonisation. There is an index of thirty-five pages.

A TEXT-BOOK ON FIELD ASTRONOMY FOR ENGINEERS.

By George C. Comstock. Cloth, 9 x 6 ins., 10 + 202 pp., illus. New York, John Wiley & Son, 1902. $2.50.

The author states in the preface that the present work is not designed for professional students of astronomy, but for another and larger class, found in technical colleges. For many years it has been the author's duty to teach to students of engineering the elements of practical astronomy, and the experience thus acquired has gradually produced the unconventional views that find expression in the present text, and which, to the author's mind, are justified by the following considerations: In the engineering curriculum, work in astronomy is a part of the technical and professional training of students who have no purpose to become astronomers. Under these circumstances it seems to be the duty of the instructor to select for presentation those parts of astronomical practice most closely related to the work of the future engineer, and, with reference to the narrow limits of time allotted the subject, to keep in the background many collateral matters that are of primary interest and importance to the student of astronomy as a science. The chapter headings are: Introductory; Co-ordinates; Time; Corrections of Co-ordinates; Rough Determinations; Approximate Determinations; Instruments; Accurate Determinations; The Transit Instrument; Bibliography; Orientation Tables. There is an index of two pages.

METALLURGICAL LABORATORY NOTES.

By Henry M. Howe. Cloth, 9 x 6 ins., 14 + 140 pp., illus. Boston Testing Laboratories, Boston, 1902. $2.50.

The preface states that metallurgical laboratory instruction of the established type reproduces the industrial metallurgical processes, each as a whole, and with such fidelity to actual industrial practice as is attainable. This, which may be called "Applied Metallurgy," seems to the author to have inherent and very grave faults. In its place he has tried to work out a system of what may be called "Theoretical," or better, "Analytical Metallurgy," with the aim of teaching, not individual processes each as a whole, but the individual underlying principles each by itself. This he has tried to do by means of a series of distinct experiments, each testing directly one or more of these principles. With a few exceptions, all the experiments in this work have been carried out either in the metallurgical laboratory of the School of Mines of Columbia University, or earlier in the author's private laboratory, and either exactly in the form here given, or in a form of which the present is a slight modification. The tables at the end of the work are original here, except that of atomic weights, and also, except in a sense, that of melting points of silicates. The book is divided into the following groups: Squad Experiments and Others for a Short Course in Metallurgy; Pyrometry and Calorimetry; Melting Points of Silicates, etc.; Properties of Refractory Materials; Iron and Steel; Non-Ferrous Metals. There is an index of ten pages.

THE PHYSICAL GEOGRAPHY OF NEW YORK STATE.

By Ralph S. Tarr. (With a Chapter on Climate by E. T. Turner.) Cloth, 9 x 6 ins., 13 + 397 pp., illus. New York, The Macmillan Company, 1902. $3.50 net.

It is stated in the preface that at the request of the American Geographical Society in 1896 a series of articles on the Physical Geography of New York State was undertaken and the first number appeared in the Bulletin of the American Geographical Society, Vol. XXVIII, 1896. When these articles were begun, it was the author's intention to cover the subject in two or three numbers; but, after getting well into the task, it became evident that to cover the field with any fulness would require many more chapters than were originally planned, and, therefore, the series lengthened out to twelve numbers and was not finished until 1900. In the main, this book is a reprint of the articles as published in the Bulletin, but there has necessarily been a certain amount of revision, and many of the more important papers on the subject which have appeared since the original publication of the articles have been made use of, so that the bibliography has been brought down to date. The chapter headings are: General Physical Features; The Mountains of the State; Plains and Plateaus; The Influence of the Glacial Period upon Topography; The Rivers of New York; Lakes and Swamps; Origin of the Basins of the Great Lakes; Post-Glacial History of the Great Lakes; Niagara; The Shore Lines; The Climate of New York; Influence of Physiographic Features upon the Industrial Development of the State. There is an index of eight pages.

EXPÉRIENCES SUR LE TRAVAIL DES MACHINES-OUTILS.

Pour les Métaux. Par C. Codron. Paper, 11 x 9 ins., 2 + 267 pp., illus. Paris, Vve. Ch. Dunod, 1902. 12 fr. 50.

The preface states that while continuing the publication of the study on the work of machine-tools in the *Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, the author has thought that it would be advantageous to bring out the first part for the public who are interested in mechanical arts. The Contents are: Meulage; Essais de meulage; Essais à vitesse variable; Tranchage; Tranchage du plomb, du cuivre, du fer, de l'acier; Emploi de deux tranches opposées; Coupe avec deux molettes; Essais de pénétration d'une molette; Coupe des tubes; Cisaillage; Essais de cisaillage à lames parellèles; Cisaillage avec lames obliques; Essais de cisaillage avec lames circulaires; Essais de cisailleuse; Essais de cisaillage à vitesse variable; Poinçonnage; Formes des débouchures; Essais divers de poinçonnage: Poinçons aléseurs à tranchants multiples; Alésage de trous à la broche; Poinçonnage progressif ; Essais de poinçonneuse; Essais de poinçonnage multiple; Poinçonnage sur épaisseurs multiples.

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BY PURCHASE.

Treatise on Wooden Trestle Bridges According to the Present Practice on American Railroads. By Wolcott C. Foster. Third Revised and Enlarged Edition. New York, John Wiley & Sons; London, Chapman & Hall, 1902.

The Practical Application of the Slide Valve and Link Motion to Stationary, Portable, Locomotive, and Marine Engines, with New and Simple Methods for Proportioning the Parts. By William S. Auchincloss, M. Am. Soc. C. E. Fourteenth Edition, Revised. New York, D. Van Nostrand Company, 1901.

Annual Report of the Signal Officer to the Secretary of War, 1871, '73, '74. Washington, Government Printing Office, 1871–74.

Army Meteorological Register for Twelve Years, from 1843 to 1854, Inclusive, Compiled from Observations Made by the Officers of the Medical Department of the Army, at the Military Posts of the United States, Prepared under the Direction of Brevet Brigadier General Thomas Lawson, Surgeon General, United States Army. Washington, A. O. P. Nicholson, 1855.

Topographical Drawing and Sketching, Including Applications of Photography. By Henry A. Reed. Fourth Edition—Revised and Enlarged. 2 vol. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1897.

Building Construction and Superintendence. By F. E. Kidder. Part I, Fifth Edition. Part II, Fourth Edition. New York, William T. Comstock, 1902.

Architects' and Builders' Pocket-Book of Mensuration, Geometry, Geometrical Problems, Trigonometrical Formulas and Tables, Strength and Stability of Foundations, Walls, Buttresses, Piers, Arches, Posts, Ties, Beams, Girders, Trusses, Floors, Roofs, etc. In Addition to which is a Great Amount of Condensed Information: Statistics and Tables Relating to Carpentry, Masonry, Drainage, Painting and Glazing, Plumbing, Plastering, Roofing, Heating and Ventilation, Weights of Materials, Capacity and Dimensions of Noted Churches, Theatres, Domes, Towers, Spires, etc., with a Great Variety of Miscellaneous Information. By Frank E. Kidder. Thirteenth Edition, Revised and Greatly Enlarged. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1902.

SUMMARY OF ACCESSIONS.

From December 10th, 1902, to January 13th, 1903.

Donations (including 61 duplicates and 10 numbers completing volumes of periodicals)	269
By Purchase	10
Total	279

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MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(December 10th, 1902 to January 13th, 1903.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Eng. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des Ecôle Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France. Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c
(47) *Mechanical Engineer*, Manchester, England.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.

LIST OF ARTICLES.

Bridge.

The Footbridge for Building the Cables of the New East River Bridge.* Isaac Harby, Jun. Am. Soc. C. E. (54) Vol. xlix.
The Widening of London Bridge.* (12) Serial beginning Dec. 5.
Construction of the Blackwell's Island Bridge Masonry.* (14) Dec. 18.
The Design and Construction of a 50-ft. Brick Arch Culvert across Rock Creek, Washington, D. C.* W. J. Douglas. (13) Dec. 25.
Bridges, Foundations, Docks and Water Fronts, and Canals. William H. Burr, M. Am. Soc. C. E., M. Inst. C. E. (14) Jan. 3.
The Monongahela Bridge.* (14) Jan. 3.
The Mississippi River Bridge at Thebes.* (15) Jan. 9.
Le Pont Monumental de Luxembourg.* Cart. (38) Dec.
Nouvelle Méthode pour le Calcul du Moment de Résistance *i/v* et du Moment d'Inertie I.* Lathuillière. (36) Dec. 10.

Electrical.

Investigations of Magnetic Fields, with reference to Ore-Concentration.* Walter R. Crane. (56) Vol. xxxi.
Three-Wire System for Variable Speed Motor Work.* N. W. Storer. (42) Dec.
The Storage Battery as a Factor in Speed Control.* H. Blohs. (42) Dec.
Electrically Operated Coal Hoist Having Variable Speed Control.* P. O. Keilholtz. (42) Dec.
A Series-Parallel System of Speed Control.* Geo. W. Fowler. (42) Dec.
Multiple Unit, Voltage Speed Control for Trunk Line Service.* H. Ward Leonard. (42) Dec.
Continuous Current Motors for Machine Tools. F. O. Blackwell. (42) Dec.
The Use of Specification Forms in Designing Dynamo Machinery, and the Design of a Rotary Converter. H. M. Hobart. (26) Serial beginning Dec. 5.
Commutation.* H. St. Hill Mawdsley. (26) Dec. 5.
Experiments on the Application of Pupin's System to Telephone Circuits. F. Dolezalek and A. Ebeling. (26) Serial beginning Dec. 12.
Cleckheaton Electricity Works.* (26) Dec. 12.
Imperial Telegraphic Communication. Charles Bright. (26) Serial beginning Dec. 12.
Some Limits in Heavy Electrical Engineering. James Swinburne. (Presidential address delivered before the Inst. of Elec. Engrs.) (47) Serial beginning Dec. 18; (26) Serial beginning Dec. 12.
Electrochemical Oscillations.* Woolsey McA. Johnson. (27) Dec. 13.
Three-Phase Measurements.* A. S. McAllister. (27) Dec. 13.
The Manufacture and Laying of the Vera Cruz-Frontera-Campeche Cable for the Mexican Government.* (27) Dec. 13.
Photometry for Electricians and Others. (66) Dec. 16.
On Electrons. *Sir* Oliver Lodge. (Paper read before the Inst. Elec. Engrs.) (26) Serial beginning Dec. 19.
A Criticism of Present-Day Continuous-Current Designing. Fred. W. Davies. (26) Dec. 19.
Electric Heating and Lighting in the Carnegie Residence, New York.* (14) Dec. 20.
Ruhmer's Photoelectric Telephone.* A. Frederick Collins. (27) Dec. 20.
A French System of Train Lighting. P. Letheule. (27) Dec. 20.
Electric Furnaces.* Clinton Paul Townsend. (27) Dec. 20.
The New Niagara.* Waldon Fawcett. (62) Dec. 25.
Electricity Supply in Hastings.* (26) Dec. 26.
The Designing of Polyphase Current Machines. David Bergman. (26) Dec. 26.
800-Kilowatt Triple-Expansion Engine; Middlesbrough Electricity Works.* (11) Dec. 26.
Electrically-Driven Quadruplex Two-Stage Compressors, and Their Use for Power in Collieries and Works.* (22) Dec. 26.
The Cauvery Falls Power Plant.* (16) Dec. 27.
The Cost of Electric Light and Electric Light Plants to Municipalities. (60) Jan.
Electric Power in India; the Cauvery Falls Plant.* J. H. Thomson. (10) Jan.
Economy in the Design and Operation of Electric Plants.* Percival Robert Moses. (9) Jan.
Modern Tendencies in the Development and Transmission of Power. John Joseph Flather, M. Am. Soc. M. E. (Abstract of Vice-Presidential address before the Am. Assoc. for the Advancement of Science.) (13) Jan. 1.
The Water and Electric Power System of the Pike's Peak Power Co., Col.* W. P. Hardesty. (13) Jan. 1.
Electrical Distribution of Power in Industrial Establishments. Cecil P. Poole, Member A. I. E. E. (14) Jan. 3.
The First Three-Phase Power Transmission Plant in Europe Operating at 30,000 Volts.* H. Behn-Eschenburg. (27) Jan. 3.
Analysis of Wireless Telegraph Systems in 1902.* A. Frederick Collins. (27) Jan. 3.
The Relation of Synchronous Impedance to the Impedance at Standstill. F. Townsend, H. P. Freund, W. I. Reich. (27) Jan. 3.
Telephone Cables, Cost of Cable Wire Plant. Arthur V. Abbott. (27) Jan. 3.
New Shops of the British Thomson-Houston Company.* (27) Jan. 3.
Three-Phase Measurements. Leslie L. Perry. (27) Jan. 10.
Electrical Supply from Water Power at Portland, Me.* Alton D. Adams. (27) Jan. 10.

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* Illustrated.

Electrical—(Continued).

Mesure à l'Aide d'un Seul Wattmètre de la Puissance dans les Circuits Équilibrés, Parcourus par des Courants Triphasés.* Octave Robert. (36) Dec. 10.
Station Centrale Électrique de Waterside à New York.* F. Drouin. (33) Dec. 13.
Fabrication des Lampes Electriques à Incandescence.* Paul Razous. (33) Dec. 20.

Marine.

The Submarine Torpedo Boat, *Protector*.* (12) Dec. 12.
The Application of Turbine Propulsion to Passenger Vessels.* Herbert C. Fyfe. (46) Dec. 13.
The New German Battleship *H*.* (12) Dec. 19.
The New Armored Cruisers *Tennessee* and *Washington*.* (46) Dec. 27.
Developing a British War Post, an Outlay of £4 500 000 (Dockyard Extension).* Archibald S. Hurd. (10) Jan.
A New Departure in British Cruiser Machinery; the Question of Water-Tube Boilers.* George Halliday. (10) Jan.
The New York Shipbuilding Company's Plant, Camden, N. J.* (14) Serial beginning Jan. 3.

Mechanical.

Problems in Hauling and Hoisting. Alexander Bowie. (56) Vol. xxxi.
The D'Auria Air-Compressor.* Henry G. Morris. (56) Vol. xxxi.
Machine Tools. Jas. K. Cullen. (61) Nov. 18.
Some Notes on Several Types of Mantles for Incandescent Gas Burners. William Lincoln Smith. (7) Dec.
The Operation of Machine Shops by Individual Electric Motors. R. T. E. Lozier. (42) Dec.
Modern Handling of Iron Ore on the Great Lakes.* Jas. N. Hatch. (4) Dec.
Foundry Management in the New Century.* Robert Buchanan. (9) Serial beginning Dec.
Flow Through Centrifugal Pumps.* Jas. Alex. Smith. (Paper read before the Victorian Inst. of Engrs.) (11) Dec. 5.
The Brunck System of By-Product Coke Ovens.* (22) Dec. 5.
The Lighting of Factories. J. H. Brearley. (Paper read before the Manchester District Inst. of Gas Engrs.) (66) Dec. 9.
Briquetting Iron Flue Dust. R. M. Hale. (20) Dec. 11.
High Pressure Steam Piping. William Andrews. (Paper read before the Engine Builders' Assoc. of the U. S.) (20) Dec. 11; (13) Dec. 18; (14) Dec. 20.
Manufacture of Steel by the Electric Furnace.* (Translation with additions by P. McN. Bennie of a paper by Charles Bertolus of St. Etienne, France, entitled, "Notice sur la Fabrication des Aciers au Four Electrique.") (20) Dec. 11.
The Use of Blast Furnace Gas in Gas Engines.* Cecil A. Cochrane. (Abstract of Paper read before the Cleveland Inst. Engrs.) (22) Dec. 12; (11) Serial beginning Dec. 12.
Gas Engine Diagrams.* W. H. Booth. (26) Dec. 12.
Gas Engines for Electric Stations. G. H. Baillie. (12) Dec. 12.
Plant for Testing Cables at High Pressures. Stuart A. Russell. (12) Dec. 12.
Three Cylinder Compound Gas Engine.* (12) Dec. 12.
Compressed Air as a Transportation Agent.* Waldon Fawcett. (46) Dec. 13.
A Combined Charging and Drawing Machine; Remarkable Figures as to Labour in Machine Working.* (66) Dec. 16.
New Gas-Works for Glyncorrwg; a Design for a Small Plant.* (66) Dec. 16.
Water Controlled Forter Reversing Valve.* (20) Dec. 18.
Compression of Ingots.* A. Harmet. (Paper read before the Iron and Steel Institute of Düsseldorf.) (62) Dec. 18.
The Development of Tool Steel. Edmund L. French. (Read before Am. Assoc. for the Advancement of Science, Pittsburg.) (62) Dec. 18.
The Double-Acting Two-Cycle Gas Engine, Körting's Patent. (22) Dec. 19.
Gas Engines for Central Stations. (26) Dec. 19.
The Use of Blast-Furnace Gas in Gas Engines. Cecil Cochrane. (Abstract of Paper read at meeting of Cleveland Inst. Engrs.) (57) Dec. 19.
Regulator for Air or Gas Compressors.* (47) Dec. 20.
Electrically-Operated Charging Machines, Hoists, Hauling, and Conveying Apparatus in Iron and Steel Works.* Frank C. Perkins. (19) Dec. 20.
Steam Turbines; with Special Reference to the De Laval Turbine.* Konrad Andersson. (Paper read before the Inst. of Engrs. and Shipbuilders in Scotland.) (47) Serial beginning Dec. 6; (abstract) (17) Dec. 20.
Notes on Recent Experiments with Mechanical Lamps.* W. R. Crane. (16) Dec. 20.
Cause of Increased Consumption in Gas and Gasoline Engines. Albert Stritmatter. (62) Dec. 25.
Steam Superheaters. (62) Dec. 25.
The American Ball Duplex Compound Engine.* (40) Dec. 26.
The Future of Coal Gas and Allied Illuminants. Vivian B. Lewes. (29) Serial beginning Dec. 26.
The Machinery for the Consett Iron Company's Garesfield and Derwenthaugh Inclined Railway.* (22) Dec. 26.

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* Illustrated.

Mechanical—(Continued).

300-Kilowatt Triple-Expansion Engine; Middlesbrough Electricity Works.* (11) Dec. 26.

Steel Ball-Bearings.* (11) Dec. 26.

A Thread-Milling Machine.* (15) Dec. 26.

Municipal Motor Wagons.* Archibald Sharp, A. M. Inst. C. E. (Paper read at Conference of Engrs. and Surveyors, Sanitary Inst. Cong.) (47) Dec. 27.

Flywheel Capacity for Engine-Driven Alternators. Walter I. Slichter. (47) Dec. 27.

The Körting Gas Engine.* (18) Dec. 27.

Large Stop Valves for High Pressure Steam.* J. Hamilton Gibson. (Paper read before the North of England Inst. of Engrs. and Shipbuilders.) (57) Dec. 24; (47) Serial beginning Dec. 27.

Water Tube Boilers.* (19) Dec. 27.

Superheated Steam. E. H. Foster, M. Am. Soc. M. E. (Condensed from paper read at meeting of Engine Builders' Assoc. of the U. S.) (13) Dec. 11; (19) Dec. 27.

Some Economical Gas Burning Appliances.* W. H. Test. (24) Dec. 29.

Notable Experiences with blue water gas at Ilford. (66) Dec. 30.

Fuel Briquettes in Germany, How They Are Made and Used.* Frank H. Mason. (10) Jan.

Cut Gearing and Some American Machinery for Its Manufacture.* Oscar J. Beale. (10) Jan.

Machine Tool Progress, Feeds and Drives.* C. W. Obert. (25) Serial beginning Jan.

Some Interesting New Driving-Wheel Lathes, Extra Heavy and of Special Design for Very Rapid Cutting.* (25) Jan.

The Williams Engine.* (64) Jan.

The Use of Surveying Instruments in Machine Shop Practice.* (41) Jan.

The Milling-Cutter Applied to the Production of Screw-Threads.* (13) Jan. 1.

Notes on the Evolution of the Drop Hammer for Die Forging. E. W. Merrill, Jr. (13) Jan. 1.

Diescher Coal Washing System. (62) Jan. 1.

Steam Engine *vs.* Internal Combustion Engine, for Electric Power Generating Plants.* Frank C. Perkins. (41) Jan. 1.

Smokeless Combustion of Bituminous Fuels. W. H. Booth. (Extracts from Paper read before the British Assoc.) (18) Jan. 3.

The Development of Steam Power Plants. Geo. H. Barrus, M. Am. Soc. M. E. (14) Jan. 3.

The Hult Rotary Steam Engine.* (62) Jan. 8.

Some Requirements of Machine Tool Operation; with Special Reference to the Motor Drive.* Charles Day. (Condensed from paper read before the N. Y. Elec. Soc.) (13) Jan. 8; (20) Jan. 8; (15) Jan. 9; (27) Jan. 10; (25) Jan. 9.

New Power Plant, Michigan Central Shops, Jackson, Mich.* (18) Jan. 10.

Pompes à Grande Vitesse.* Lecuir. (37) Nov.

Tour Vertical Bullard.* (37) Nov.

Appareils de Sûreté des Chaudières à Vapeur.* F. Sinigaglia. (37) Dec.

Note sur les Aéromoteurs.* E. Sohie. (30) Dec.

Le Funiculaire de Weehawken (États-Unis).* (33) Dec. 6.

Calculs des Parois et Armatures des Tuyaux à Section Circulaire, Poses sur le Sol.* C. Birault. (33) Serial beginning Dec. 13.

Emploi de l'Air Comprimé dans les Chautiers de Construction.* A. Abraham. (33) Serial beginning Dec. 20.

Metallurgical.

A Rapid Assay for Silver and Gold in Metallic Copper. Geo. L. Heath. (56) Vol. xxxi.

Concentrating-Tests and Calculations. Otto F. Pfordte. (56) Vol. xxxi.

The Forecast of Chemical Reactions from Algebraic Signs of the Quantities of Heat Liberated. H. Le Chatelier. (56) Vol. xxxi.

Chromite as a Hearth-Lining for a Furnace Smelting Copper-Ore.* William Glenn. (56) Vol. xxxi.

A Study of the Effect of Heat-Treatment on Crucible Steel Containing One Per Cent. of Carbon.* George W. Sargent. (56) Vol. xxxi.

The Constitution of Cast-Iron, with Remarks on Current Opinions Concerning It.* H. M. Howe. (56) Vol. xxxi.

The Use of the Tri-Axial Diagram in the Calculation of Slags.* Ernest A. Hersam. (56) Vol. xxxi.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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PROGRESS REPORT OF SPECIAL COMMITTEE ON UNIFORM TESTS OF CEMENT.

Presented at the Annual Meeting, January 21st, 1903.

Your Committee on Uniform Tests of Cement has devoted much time, and given very careful consideration, to the subject. Frequent meetings have been held, and a number of investigations carried on, some of which cannot be finally reported at this time.

On several matters which have been considered, such as the substitution of a natural sand for the standard quartz, and the tests for the normal consistency and constancy of volume, the Committee has not reached final conclusions.

While not prepared to submit a final report, the Committee feels that it should present a report of progress in order that the Society may be informed of the results of its investigations and conclusions.

In order to do full justice to the subject under consideration, it will be necessary to compile and report the results of the experiments now under way, and your Committee asks, therefore, that it be continued.

Sampling.

1.—*Selection of Sample.*—The selection of the sample for testing is a detail that must be left to the discretion of the engineer; the number and the quantity to be taken from each package will depend largely on the importance of the work, the number of tests to be made and the facilities for making them.

Note.—Discussion on this report is requested.

2.—The sample shall be a fair average of the contents of the package; it is recommended that, where conditions permit, one barrel in every ten be sampled.

3.—All samples should be passed through a sieve having twenty meshes per linear inch, in order to break up lumps and remove foreign material; this is also a very effective method for mixing them together in order to obtain an average. For determining the characteristics of a shipment of cement, the individual samples may be mixed and the average tested; where time will permit, however, it is recommended that they be tested separately.

4.—*Method of Sampling.*—Cement in barrels should be sampled through a hole made in the center of one of the staves, midway between the heads, or in the head, by means of an auger or a sampling iron similar to that used by sugar inspectors. If in bags, it should be taken from surface to center.

CHEMICAL ANALYSIS.

5.—*Significance.*—Chemical analysis may render valuable service in the detection of adulteration of cement with considerable amounts of inert material, such as slag or ground limestone. It is of use, also, in determining whether certain constituents, believed to be harmful when in excess of a certain percentage, as magnesia and sulphuric anhydride, are present in inadmissible proportions. While not recommending a definite limit for these impurities, the Committee would suggest that the most recent and reliable evidence appears to indicate that magnesia to the amount of 5%, and sulphuric anhydride to the amount of 1.75%, may safely be considered harmless.

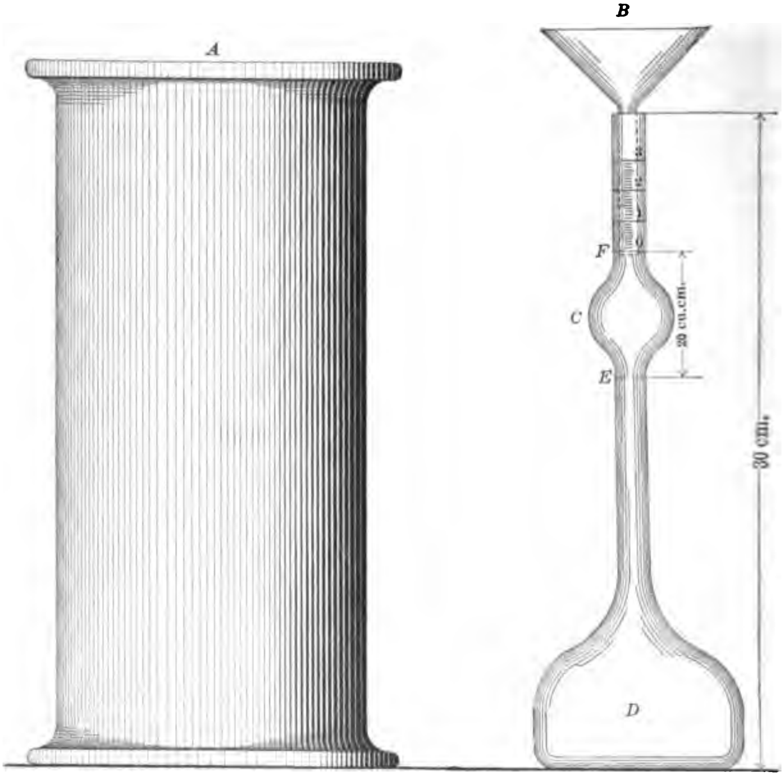
6.—The determination of the principal constituents of cement—silica, alumina, iron oxide and lime—is not conclusive as an indication of quality. Faulty character of cement results more frequently from imperfect preparation of the raw material or defective burning than from incorrect proportions of the constituents. Cement made from very finely-ground material, and thoroughly burned, may contain much more lime than the amount usually present and still be perfectly sound. On the other hand, cements low in lime may, on account of careless preparation of the raw material, be of dangerous character. Further, the ash of the fuel used in burning may so greatly modify the composition of the product as largely to destroy the significance of the results of analysis.

7.—*Method.*—As a method to be followed for the analysis of cement, that proposed by the Committee on Uniformity in the Analysis of Materials for the Portland Cement Industry, of the New York Section of the Society for Chemical Industry, and published in the *Journal* of the Society for January 15th, 1902, is recommended.

Specific Gravity.

8.—*Significance.*—The specific gravity of cement is lowered by underburning, adulteration and hydration, but the adulteration must be in considerable quantity to affect the results appreciably.

9.—Inasmuch as the differences in specific gravity are usually very small, great care must be exercised in making the determination.



LE CHATELIER'S SPECIFIC GRAVITY APPARATUS.

Fig. 1.

10.—When properly made, this test affords a quick check for underburning or adulteration.

11.—*Apparatus and Method.*—The determination of specific gravity is most conveniently made with Le Chatelier's apparatus. This consists of a flask (*D*), Fig. 1, of 120 cu. cm. (7.32 cu. ins.) capacity the neck of which is about 20 cm. (7.87 ins.) long; in the middle of this neck is a bulb (*C*), above and below which are two marks (*F*) and (*E*); the volume between these marks is 20 cu. cm. (1.22 cu. ins.). The neck has a diameter of about 9 mm. (0.35 in.), and is graduated into tenths of cubic centimeters above the bulb.

12.—Benzine (62° Baumé naphtha), or kerosene free from water, should be used in making the determination.

13.—The specific gravity can be determined in two ways:

(1) The flask is filled with either of these liquids to the lower mark (*E*), and 64 gr. (2.25 oz.) of powder, previously dried at 100° Cent. (212° Fahr.) and cooled to the temperature of this liquid, is gradually introduced through the funnel (*B*) [the stem of which extends into the flask to the top of the bulb (*C*)], until the upper mark (*F*) is reached. The difference in weight between the cement remaining and the original quantity (64 gr.) is the weight which has displaced 20 cu. cm.

14.—(2) The whole quantity of the powder is introduced, and the level of the liquid rises to some division of the graduated neck. This reading plus 20 cu. cm. is the volume displaced by 64 gr. of the powder.

15.—The specific gravity is then obtained from the formula:

$$\text{Specific Gravity} = \frac{\text{Weight of Cement}}{\text{Displaced Volume.}}$$

16.—The flask, during the operation, is kept immersed in water in a jar (*A*), in order to avoid variations in the temperature of the liquid. The results should agree within 0.01.

17.—A convenient method for cleaning the apparatus is as follows: The flask is inverted over a large vessel, preferably a glass jar, and shaken vertically until the liquid starts to flow freely; it is then held still in a vertical position until empty; the remaining traces of cement can be removed in a similar manner by pouring into the flask a small quantity of clean liquid and repeating the operation.

18.—More accurate determinations may be made with the picnometer.

FINENESS.

19.—*Significance.*—It is generally accepted that the coarser particles in cement are practically inert, and it is only the extremely fine powder that possesses adhesive or cementing qualities. The more finely cement is pulverized, all other conditions being the same, the more sand it will carry and produce a mortar of a given strength.

20.—The degree of final pulverization which the cement receives at the place of manufacture is ascertained by measuring the residue retained on certain sieves. Those known as the No. 100 and No. 200 sieves are recommended for this purpose.

21.—*Apparatus.*—The sieves should be circular, about 20 cm. (7.87 ins.) in diameter, 6 cm. (2.36 ins.) high, and provided with a pan, 5 cm. (1.97 ins.) deep, and a cover.

22.—The wire cloth should be woven (not twilled) from brass wire having the following diameters:

No. 100, 0.0045 in.; No. 200, 0.0024 in.

23.—This cloth should be mounted on the frames without distortion; the mesh should be regular in spacing and be within the following limits:

No. 100, 96 to 100 meshes to the linear inch.
No. 200, 188 to 200 " " " "

24.—Fifty grams (1.76 oz.) or 100 gr. (3.52 oz.) should be used for the test, and dried at a temperature of 100° Cent. (212° Fahr.) prior to sieving.

25.—*Method.*—The Committee, after careful investigation, has reached the conclusion that mechanical sieving is not as practicable or efficient as hand work, and, therefore, recommends the following method:

26.—The thoroughly dried and coarsely screened sample is weighed and placed on the No. 200 sieve, which, with pan and cover attached, is held in one hand in a slightly inclined position, and moved forward and backward, at the same time striking the side gently with the palm of the other hand, at the rate of about 200 strokes per minute. The operation is continued until not more than one-tenth of 1% passes through after one minute of continuous sieving. The residue is weighed, then placed on the No. 100 sieve and the operation repeated. The work may be expedited by placing in the sieve a small quantity of large shot. The results should be reported to the nearest tenth of 1 per cent.

NORMAL CONSISTENCY.

27.—*Significance.*—The use of a proper percentage of water in making the pastes* from which pats, tests of setting and briquettes are made, is exceedingly important, and affects vitally the results obtained.

28.—The determination consists in measuring the amount of water required to reduce the cement to a given state of plasticity, or to what is usually designated the normal consistency.

29.—Various methods have been proposed for making this determination, none of which has been found entirely satisfactory. The Committee recommends the following:

30.—*Method. Vicat Needle Apparatus.*—This consists of a frame (*K*), Fig. 2, bearing a movable rod (*L*), with the cap (*A*) at one end, and at the other end the cylinder (*B*), 1 cm. (0.39) in. in diameter, the cap, rod and cylinder weighing 300 gr. (10.58 oz.). The rod, which can be held in any desired position by a screw (*F*), carries an indicator, which moves over a scale (graduated to centimeters) attached to the frame (*K*). The paste is held by a conical, hard-rubber ring (*I*), 7 cm. (2.76 ins.) in diameter at the base, 4 cm. (1.57 ins.) high, resting on a glass plate (*J*), about 10 cm. (3.94 ins.) square.

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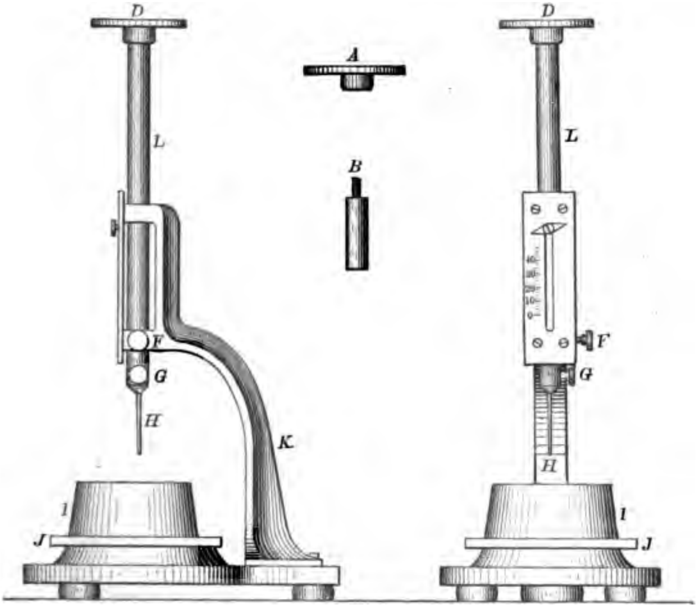
* The term "paste" is used in this report to designate a mixture of cement and water, and the word "mortar" a mixture of cement, sand and water.

31.—In making the determination, 500 gr. (17.64 oz.) of cement are kneaded into a paste, as described in Paragraph 58, and quickly formed into a ball with the hands, completing the operation by tossing it six times from one hand to the other, maintained 6 ins. apart; the ball is then pressed into the rubber ring, through the larger opening, smoothed off, and placed on a glass plate (on its large end) and the smaller end smoothed off with a trowel; the paste, confined in the ring, resting on the plate, is placed under the rod bearing the cylinder, which is brought in contact with the surface and quickly released.



VICAT NEEDLE.

Fig. 2.

32.—The paste is of normal consistency when the cylinder penetrates to a point in the mass 10 mm. (0.39 in.) below the top of the ring. Great care must be taken to fill the ring exactly to the top.

33.—The trial pastes are made with varying percentages of water until the correct consistency is obtained.

34.—The Committee believes that the normal consistency should produce a rather wet paste, since this consistency tends to greater uniformity in the mixing, and there is less liability of compressing the briquettes during the moulding.

35.—Having determined in this manner the proper percentage of water required to produce a neat paste of normal consistency, the proper percentage required for the sand mortars is obtained from an empirical formula.

36.—The Committee hopes to devise such a formula. The subject proves to be a very difficult one, and, although the Committee has given it much study, it is not yet prepared to make a definite recommendation.

TIME OF SETTING.

37.—*Significance.*—The object of this test is to determine the time which elapses from the moment water is added until the paste ceases to be fluid and plastic (called the "initial set"), and also the time required for it to acquire a certain degree of hardness (called the "final" or "hard set"). The former of these is the more important, since, with the commencement of setting, the process of crystallization or hardening is said to begin. As a disturbance of this process may produce a loss of strength, it is desirable to complete the operation of mixing and moulding or incorporating the mortar into the work before the cement begins to set.

38.—It is usual to measure arbitrarily the beginning and end of the setting by the penetration of weighted wires of given diameters.

39.—*Method.*—For this purpose the Vicat Needle, which has already been described in Paragraph 30, should be used.

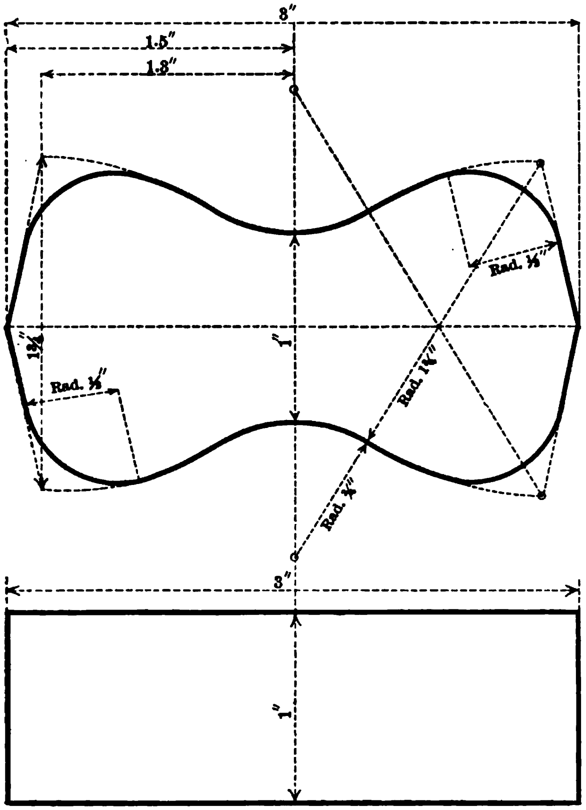
40.—In making the test, a paste of normal consistency is moulded and placed under the rod (*L*), Fig. 2, as described in Paragraph 31; this rod, bearing the cap (*D*) at one end and the needle (*H*), 1 mm. (0.039 in.) in diameter, at the other, weighing 300 gr. (10.58 oz.). The needle is then carefully brought in contact with the surface of the paste and quickly released.

41.—The setting is said to have commenced when the needle ceases to pass a point 5 mm. (0.20 in.) above the upper surface of the glass plate, and is said to have terminated the moment the needle does not sink visibly into the mass.

42.—The test pieces should be stored in moist air during the test; this is accomplished by placing them on a rack over water contained in a pan and covered with a damp cloth, the cloth to be kept away from them by means of a wire screen; or they may be stored in a moist box or closet.

43.—Care should be taken to keep the needle clean, as the collection of cement on the sides of the needle retards the penetration, while cement on the point reduces the area and tends to increase the penetration.

44.—The determination of the time of setting is only approximate, being materially affected by the temperature of the mixing water, the temperature and humidity of the air during the test, the percentage of water used, and the amount of moulding the paste receives.



DETAILS FOR BRIQUETTE.

FIG. 8.

STANDARD SAND.

45.—The Committee recognizes the grave objections to the standard quartz now generally used, especially on account of its high percentage of voids, the difficulty of compacting in the moulds, and its lack of uniformity; it has spent much time in investigating the various natural sands which appeared to be available and suitable for use.

46.—For the present, the Committee recommends the natural sand from Ottawa, Ill., screened to pass a sieve having 20 meshes per linear inch and retained on a sieve having 30 meshes per linear inch; the wires to have diameters of 0.0165 and 0.0112 in., respectively, *i. e.*, half the width of the opening in each case.

47.—The Sandusky Portland Cement Company, of Sandusky, Ohio, has agreed to undertake the preparation of this sand, and to furnish it at a price only sufficient to cover the actual cost of preparation.

FORM OF BRIQUETTE.

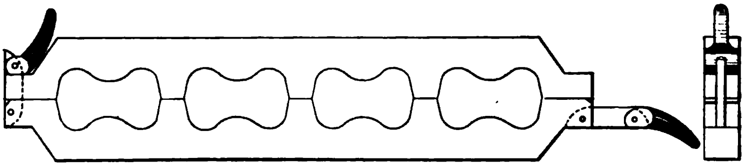
48.—While the form of the briquette recommended by a former Committee of the Society is not wholly satisfactory, this Committee is not prepared to suggest any change, other than rounding off the corners by curves of ½-in. radius, Fig. 3.

MOULDS.

49.—The moulds should be made of brass, bronze or some equally non-corrodible material, having sufficient metal in the sides to prevent spreading during moulding.

50.—Gang moulds, which permit moulding a number of briquettes at one time, are preferred by many to single moulds; since the greater quantity of mortar that can be mixed tends to produce greater uniformity in the results. The type shown in Fig. 4 is recommended.

51.—The moulds should be wiped with an oily cloth before using.



DETAILS FOR GANG MOULD.

FIG. 4.

MIXING.

52.—All proportions should be stated by weight; the quantity of water to be used should be stated as a percentage of the dry material.

53.—The metric system is recommended because of the convenient relation of the gram and the cubic centimeter.

54.—The temperature of the room and the mixing water should be as near 21° Cent. (70° Fahr.) as it is practicable to maintain it.

55.—The sand and cement should be thoroughly mixed dry. The mixing should be done on some non-absorbing surface, preferably plate glass. If the mixing must be done on an absorbing surface it should be thoroughly dampened prior to use.

56.—The quantity of material to be mixed at one time depends on the number of test pieces to be made; about 1 000 gr. (35.28 oz.) makes a convenient quantity to mix, especially by hand methods.

57.—The Committee, after investigation of the various mechanical mixing machines, has decided not to recommend any machine that has thus far been devised, for the following reasons:

(1) The tendency of most cement is to "ball up" in the machine, thereby preventing the working of it into a homogeneous paste; (2) there are no means of ascertaining when the mixing is complete without stopping the machine, and (3) the difficulty of keeping the machine clean.

58.—*Method.*—The material is weighed and placed on the mixing table, and a crater formed in the center, into which the proper percentage of clean water is poured; the material on the outer edge is turned into the crater by the aid of a trowel. As soon as the water has been absorbed, which should not require more than one minute, the operation is completed by vigorously kneading with the hands for an additional 1½ minutes, the process being similar to that used in kneading dough. A sand-glass affords a convenient guide for the time of kneading. During the operation of mixing, the hands should be protected by gloves, preferably of rubber.

MOULDING.

59.—Having worked the paste or mortar to the proper consistency, it is at once placed in the moulds by hand.

60.—The Committee has been unable to secure satisfactory results with the present moulding machines; the operation of machine moulding is very slow, and the present types permit of moulding but one briquette at a time, and are not practicable with the pastes or mortars herein recommended.

61.—*Method.*—The moulds should be filled at once, the material pressed in firmly with the fingers and smoothed off with a trowel without ramming; the material should be heaped up on the upper surface of the mould, and, in smoothing off, the trowel should be drawn over the mould in such a manner as to exert a moderate pressure on the excess material. The mould should he turned over and the operation repeated.

62.—A check upon the uniformity of the mixing and moulding is afforded by weighing the briquettes just prior to immersion, or upon removal from the moist closet. Briquettes which vary in weight more than 3% from the average should not be tested.

STORAGE OF THE TEST PIECES.

63.—During the first 24 hours after moulding, the test pieces should be kept in moist air to prevent them from drying out.

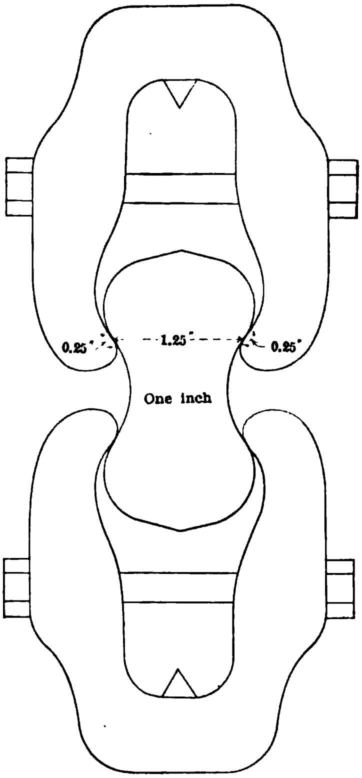
64.—A moist closet or chamber is so easily devised that the use of the damp cloth should be abandoned if possible. Covering the test pieces with a damp cloth is objectionable, as commonly used, because the cloth may dry out unequally, and, in consequence, all the test pieces are not maintained under the same condition. Where a moist closet is not available, a cloth may be used and kept uniformly wet by immersing the ends in water. It should be kept from direct contact with the test pieces by means of a wire screen or some similar arrangement.

65.—A moist closet consists of a soapstone or slate box, or a metal-lined wooden box—the metal lining being covered with felt and this felt kept wet. The bottom of the box is so constructed as to hold water, and the sides are provided with cleats for holding glass shelves on which to place the briquettes. Care should be taken to keep the air in the closet uniformly moist.

66.—After 24 hours in moist air, the test pieces for longer periods of time should be immersed in water maintained as near 21° Cent. (70° Fahr.) as practicable; they may be stored in tanks or pans, which should be of non-corrodible material.

TENSILE STRENGTH.

67.—The tests may be made on any standard machine. A solid metal clip, as shown in Fig. 5, is recommended. This clip is to be used without cushioning at the points of contact with the test specimen. The bearing at each point of contact should be ¼ in. wide, and the distance between the center of contact on the same clip should be 1¼ ins.



FORM OF CLIP.
FIG. 5.

68.—Test pieces should be broken as soon as they are removed from the water. Care should be observed in centering the briquettes in the testing machine, as cross-strains, produced by improper centering, tend to lower the breaking strength. The load should not be applied too suddenly, as it may produce vibration, the shock from which often breaks the briquette before the ultimate strength is reached. Care must be taken that the clips and the sides of the briquette be clean and free from grains of sand or dirt, which would prevent a good bearing. The load should be applied at the rate of 600 lbs. per minute. The average of the briquettes of each sample tested should be taken as the test, excluding any results which are manifestly faulty.

CONSTANCY OF VOLUME.

69.—*Significance.*—The object is to develop those qualities which tend to destroy the strength and durability of a cement. As it is highly essential to determine such qualities at once, tests of this character are for the most part made in a very short time, and are known, therefore, as accelerated tests. Failure is revealed by cracking, checking, swelling or disintegration, or all of these phenomena. A cement which remains perfectly sound is said to be of constant volume.

70.—*Methods.*—Tests for constancy of volume are divided into two classes: (1) normal tests, or those made in either air or water maintained at about 21° Cent. (70° Fahr.), and (2) accelerated tests, or those made in air, steam or water at a temperature of 45° Cent. (115° Fahr.) and upward. The test pieces should be allowed to remain 24 hours in moist air before immersion in water or steam.

71.—For these tests, pats, about 7½ cm. (2.95 ins.) in diameter, 1¼ cm. (0.49 in.) thick at the center, and tapering to a thin edge, should be made, upon a clean glass plate [about 10 cm. (3.94 ins.) square], from cement paste of normal consistency.

72.—*Normal Test.*—A pat is immersed in water maintained as near 21° Cent. (70° Fahr.) as possible for 28 days, and observed at intervals; the pat should remain firm and hard and show no signs of cracking, distortion or disintegration.

73.—*Accelerated Test.*—(*a*) A pat is placed on a shelf in a suitable vessel filled with fresh water, but without allowing it to touch the bottom. The water is then gradually raised to a temperature of 45° Cent. (115° Fahr.) and maintained at this temperature for 24 hours; or (*b*), a pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel, for 3 hours.

74.—To pass these tests satisfactorily, the pats should remain firm and hard, and show no signs of cracking, distortion or disintegration.

75.—Should the pat leave the plate, distortion may be detected best with a straight-edge applied to the surface which was in contact with the plate.

76.—In the present state of our knowledge it cannot be said that cement should necessarily be condemned simply for failure to pass the accelerated tests; nor can a cement be considered entirely satisfactory, simply because it has passed these tests.

Submitted on behalf of the Committee,

George S. Webster,
Chairman.
Richard L. Humphrey,
Secretary.

Committee.

George S. Webster,
Richard L. Humphrey,
George F. Swain,
Alfred Noble,
Louis C. Sabin,
S. B. Newberry,
Clifford Richardson,
W. B. W. Howe,
F. H. Lewis.

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PAPERS AND DISCUSSIONS.

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THE PANAMA CANAL.

By George S. Morison, Past-President, Am. Soc. C. E.

To be Presented February 18th, 1903.

On March 5th, 1902, a paper* on one of the most important features of the Panama Canal was presented by the writer. That paper was confined to a single detail, although a very important one. The present paper covers a larger scope, and takes up the principal features of the canal.

The Isthmian Canal Commission, in its report, tried to place the two canals, Panama and Nicaragua, as nearly on the same basis as possible; eliminating from each scheme special advantages and economies which might be applicable on one, but could not be on the other. There were several points on which the writer differed from his colleagues, and, while these differences do not affect the general conclusion, his individual views have influenced the present paper.

Much has been said of the great value of a tide-level canal and its unlimited capacity. This unlimited capacity is more apparent than real. A tide-level canal will require a tide lock at the Pacific end, and, although both gates can be left open at mean tide, so that the length of lock is not a limiting factor, its breadth and depth are. The difficulties of controlling floods are greater in the tide-level canal than in the canal with locks, and the advantage of a broad inland lake is lost. Still, the writer believes that the tide-level canal would be the better canal when done, but that the difficulties which would attend its construction, the greater cost, and especially the longer time involved, preclude its selection. In this paper both plans of canal are described, and comparative estimates given in some detail.

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* "The Bohio Dam," *Transactions*, Am. Soc. C. E., Vol. xlviii, p. 235.

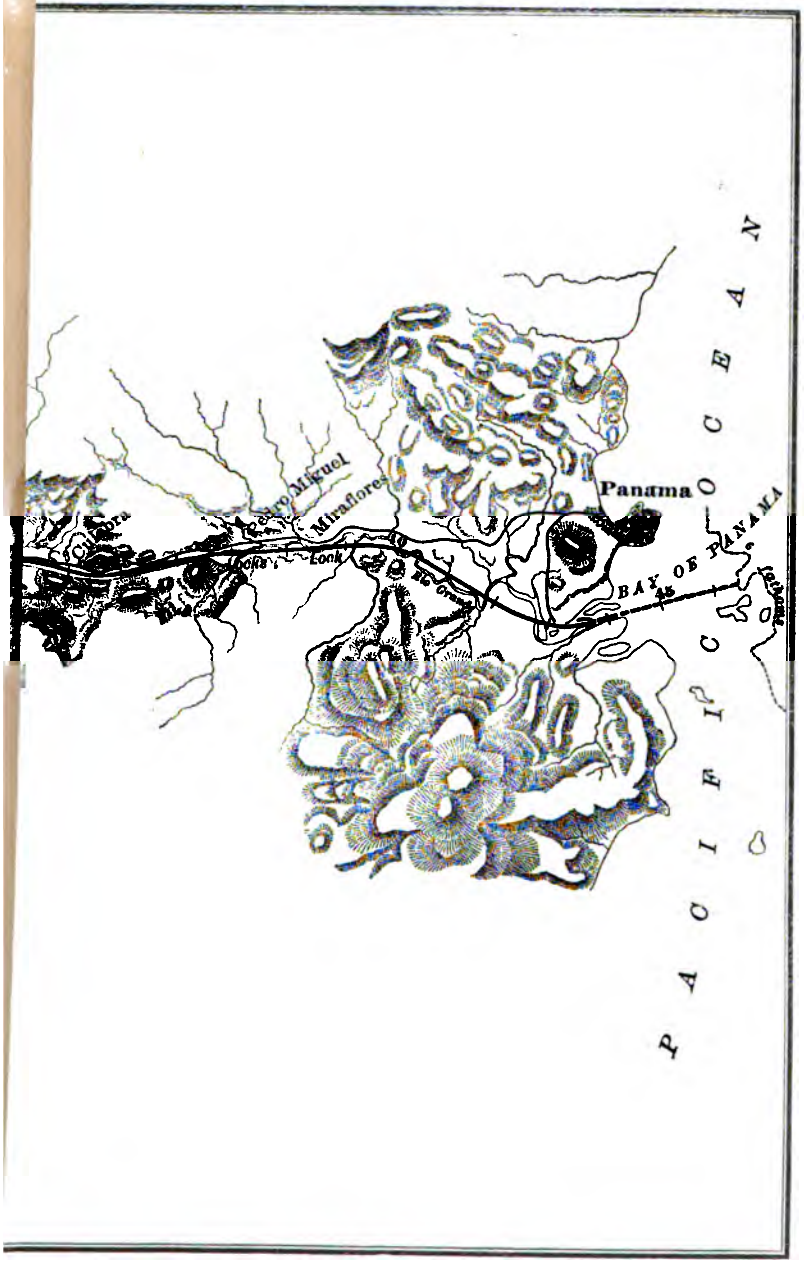
Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers with discussion in full will be published in *Transactions*.

The locks are of enormous dimensions, and, while few engineers would doubt the feasibility of locks 800 ft. long, more than 80 ft. wide, with more than 40 ft. lift, conservatism cautions us against this great lift if it can be avoided. Partly for this reason, the writer has selected the Tiger Hill Cut-Off line for the high-level canal, which permits the rise from the Atlantic to Lake Bohio to be divided into three lifts instead of two, shortens the line, and places it farther from the Chagres. The old location is not condemned, but the cut-off is preferred. The fact that by the use of an intermediate level the head of water against the dam is reduced explains the difference in the seepage figures used in this paper and those calculated in the paper on "The Bohio Dam."

General Description.

At Panama the actual width of the Isthmus from tide water to tide water, in a straight line, is only 35 miles. The continental divide is about 8 miles from the Pacific, and in places less than 300 ft. above mean tide. Between this low mountain ridge and the Atlantic lies a hilly country, intersected by streams, the drainage of which is into the Atlantic through the Chagres River. The Chagres rises in the mountains about 60 miles east of the canal location and enters the Caribbean Sea some miles west of the Atlantic terminus of the canal. The valley of the Chagres, with the low country adjacent to it, forms a natural approach from the Atlantic side. To pass from this valley to the Pacific, it is necessary to go boldly across the low ridge of the Cordilleras. The route selected by the original French company for the Panama Canal is, in a general way, the same as that on which the Panama Railroad was built 30 years before. Subject to variations of detail, the routes are practically one, and the only possible route in this part of the Isthmus. The total distance by either rail-

PLATE I.
PAPERS, AM. SOC. C. E.
JANUARY, 1903.
MORISON ON PANAMA CANAL.



road or canal from deep water to deep water is, in round numbers, 45 miles, of which 27 miles are in the Atlantic coastal plain and the valley of the Chagres; 12 miles are in the passage of the ridge, and the balance in the low lands near the Pacific. Of the actual distance from the Atlantic shore line to the Pacific shore line, not including the extensions into deep water, almost exactly two-thirds, being the portion north of Obispo, are within the drainage of the Chagres, and one-third in the crossing from the Chagres to the Pacific.

The Chagres is a tropical mountain stream, with the excessive variations which belong to such a river. Its maximum flood discharge is approximately 200 times its minimum dry-season discharge. The area of its total drainage basin, though not completely surveyed, is about 1 200 sq. miles. It has a comparatively rapid fall, which is greatest near the source. At the point where the canal leaves the Chagres valley to cross the divide, the bottom of the Chagres River is about 40 ft. above mean tide. The principal difficulties of the northern portion of the canal, from Colon to Obispo, lie in the control of the Chagres River; the principal difficulty on the remainder is the summit cut. In a tide-level canal, such as the original French Company proposed to build, these two difficulties were virtually all. With the abandonment of the tide-level scheme and the adoption of a summit level reached by locks, the problem of water supply for this summit level was added, but, as the only source of gravity supply for such summit level is the Chagres River, the problems of the control of this river and of the use of its water to feed the canal are very intimately connected.

Besides these, there are the harbors, which present difficulties, though not serious ones, at each end of the canal; the dimensions of locks which should be used, and the changes which the construction of the canal must necessarily make in the Panama Railroad. These matters call for only brief consideration.

The dimensions of the canal itself are of the utmost importance, and no estimates can be made, even of a preliminary character, without determining them. The dimensions adopted by the French Company are in a general way those of the Suez Canal. The Suez Canal is a salt-water canal throughout. The Panama Canal will be a fresh-water canal, and it will also be a warm-water canal, the water weighing 62.2 lbs. per foot, or about 3% less than the water of the ocean. The Suez

Canal has a depth of 9 m., or 29.5 ft. To accommodate ships of equal size, the Panama Canal should be at least 8 ins. deeper. The Suez Canal cannot accommodate the largest class of ships; the regulations of that canal limit the draft of ships passing through it to 7.8 m. or 25 ft. 7 ins., though ships of greater draft are sometimes taken through with the assistance of tugs. The largest steamers now plying between England and Australian ports cannot and do not pass through the Suez Canal. There is a large number of ships now in service on the Atlantic, the authorized draft of which is 32 ft. or more; one of these ships would draw 33 ft. in the Panama canal. The traffic which would pass through the Panama Canal would be of a character materially different from that which uses the Suez Canal; it would consist largely of heavy, coarse freight. As the size of a ship is, in a measure, a function of the length of voyage, it is probable that the largest class of freight carriers will use this canal. The Isthmian Canal Commission considered that the canal should have a depth of 35 ft., through which steamers drawing 32 ft. in salt water could pass without trouble, and the writer concurs in this decision.

In determining the width of the canal there is more room for difference of opinion. While depth may be considered a necessity, width is very largely a convenience. A ship can be taken through a canal with little clearance on either side, but it must be done very slowly; a much greater width will be required if any considerable speed is to be maintained, and still more if large ships are to pass each other in all portions of the canal. The dimensions adopted by the original French Company provided for a bottom width of only 22 m., or 72 ft.; the new French Company adopted a bottom width of 30 m., slightly increased in rock sections, or a little less than 100 ft. The Isthmian Canal Commission selected a bottom width of 150 ft., which was somewhat enlarged on curves. The increased width on curves in so large a canal is perhaps an over-refinement, but, in view of the experience of other great works, it is probably not wise to reduce the dimensions selected by the Commission.

Colon Harbor is virtually tideless, while Panama Bay has a tidal range of over 20 ft. The plans of the original French Company contemplated a depth of 9 m. below mean water at both termini, which would have made a channel of about 20 ft. at low water in Panama Bay. The plans of the new French Company proposed a depth of 9 m. below

low water in Panama Bay; the Isthmian Canal Commission's estimates are based on a depth of 35 ft. below mean low water in Panama Bay. A depth of 35 ft. below mean tide in Panama Bay would give 25 ft. in the canal under all conditions, 45 ft. at high water and 35 ft. for about 18 hours out of 24. In the opinion of the writer, this depth is quite as much as the demands of traffic are likely to justify.

With this preliminary statement, the main features of the canal may be described.

CONTROL OF THE CHAGRES.

The discharge of the Chagres has been made a matter of special observation by the new French Company, and these observations have been verified and amplified by Arthur P. Davis, M. Am. Soc. C. E., for the Isthmian Canal Commission. While the conclusions from such studies cannot be regarded as absolutely accurate, the general conditions, of which little was known twenty years ago, may now be considered established. The greatest flood in the Chagres, of which there is any record, occurred in 1879, prior to the beginning of work by the old French Company. The two floods of which there is the most accurate information are those of 1890 and 1893.

The area of the drainage basin of the Chagres above Bohio, the location selected by the French Company for a dam, is estimated at 875 sq. miles. This watershed may be divided for convenience into three parts: the portion above Alhajuela, the point selected by the French Company for the upper dam; the portion between Alhajuela and Gamboa, which is practically the point where the canal leaves the river; and the portion between Gamboa and Bohio. The area of the upper division is approximately 510 sq. miles, of the middle division 135 sq. miles, and of the lower division 230 sq. miles. The areas of the watersheds above these three points, will, therefore, be as follows:

	Square miles.	Percentages.
Alhajuela	510	58
Gamboa	645	74
Bohio	875	100

The data concerning the flood of 1879 are meager, and consist only of water marks from which the discharge has been calculated on various assumptions, while there is no accurate information by which the duration of the flood or the aggregate discharge can be even approximately determined. The conclusions, generally, are to the effect that it was in excess of 70 000 cu. ft. per second at Gamboa and 100 000 cu. ft. per second at Bohio. The general opinion has been that these figures are too high, but Mr. Davis thinks that there is a possibility that they are too low and that the flood may have been nearly 100 000 cu. ft. per second at Gamboa, and have exceeded 130 000 cu. ft. per second at Bohio. The flood of 1890 attained a maximum of 75 000 cu. ft. per second at Bohio, and that of 1893 fell below 50 000 cu. ft. per second. All these floods were of very short duration, the average discharge of the Chagres being about 2 000 cu. ft. per second at Alhajuela, 2 500 cu. ft. at Gamboa, and 4 000 cu. ft. at Bohio. The time in which the discharge at Gamboa would exceed 35 000 cu. ft. per second, or that at Bohio 50 000 cu. ft. per second, would probably not be more than ten days in twenty years. A suspension of traffic during these few days would not seriously reduce the value of the canal.

If a flood of 35 000 cu. ft. per second coming from the upper Chagres at Gamboa and of 50 000 cu. ft. at Bohio could be so regulated that it would not produce a speed much exceeding 3 ft. per second in the navigable portions of the canal the commercial requirements would be met. The canal, however, must be so designed that a maximum flood would do no permanent harm, and this means a probable discharge of 100 000 cu. ft. per second at Bohio, with the possibility that 140 000 cu. ft. per second should be provided for. A speed of 3.3 ft. (1 m.) per second could be allowed in the canal without disturbing navigation; a speed of 5 ft. per second could be allowed without permanent injury to the work.

With these conditions, a channel of 15 000 sq. ft. cross-section would carry off a flood of 50 000 cu. ft. per second without interfering with navigation, and of 75 000 cu. ft. per second without injury to the canal. If a tide-level canal is to be built, it must either be given these dimensions in the Chagres Valley or independent channels must be provided to carry off the discharge of the river. As the canal is in the lowest part of the valley, the construction of these channels would be a matter of serious difficulty, and the simplest solution would be to make a canal large enough to take the full discharge, which would have the further advantage of furnishing a very large canal, in which navigation, under ordinary conditions, would be especially easy; this would mean a canal with a bottom width of about 400 ft. An approximate estimate shows that the total amount of excavation for such a canal between Colon and Obispo would be 150 000 000 cu. yds., about one-sixth of which is likely to be rock. This channel, however, has practically no factor of safety, and, if the flood of 1879 should be repeated, it might prove inadequate. By building the dam proposed by the French Company at Alhajuela the discharge above that point could be temporarily stored, and the discharge through the lower valley kept within the capacity of the proposed canal. It may be roughly estimated that the cost of this Chagres section of a tide-level canal would be about $90 000 000. While this treatment would be heroic, it is practicable, and would be satisfactory when done.

If, however, a dam could be built across the valley of the Chagres, the whole valley would be converted into a lake of such dimensions that the currents in this lake, even during the most violent floods, would not be objectionable. This is, perhaps, the greatest advantage to be gained by using locks and a summit level, it is certainly second only to the reduction in the volume of the Culebra Cut. The further down the valley this dam can be placed, the greater will be the length of valley converted into lake. The lowest point, however, which has been found in any way suitable for a dam site is at Bohio, midway between Obispo and the terminus of the canal at Colon. A site for a dam in this neighborhood has been selected by the new French Company, and the Isthmian Canal Commission concurred in the expediency of building a dam in the same vicinity. By the construction of such a dam the valley is converted into a lake between Obispo and Bohio, and this lake would extend up the upper valley of the Chagres to a distance determined by the height of the dam. The Gigante, a lateral stream coming from the west, enters the Chagres about 4 miles above Bohio, and near the head of this stream is a low summit admirably adapted for a spillway. The limits within which the range of the lake could be confined would be determined by the length of this spillway. The Isthmian Canal Commission has proposed a spillway 2 000 ft. long. Using the formula

$$Q = 3.5\,h^{\frac{3}{2}}\,l,$$

we have the following results, if l is made 2 000:

$Q =$	$h =$
50 000	3.71
75 000	4.86
100 000	5.89

It would appear, therefore, that heights of, respectively, 4, 5, and 6 ft. over the crest of the spillway would pass something more than 50 000, 75 000 and 100 000 cu. ft. per second for an indefinite period. The maximum floods, however, are of short duration, and a considerable amount would be stored in the lake, as its level is raised from the normal level to the extreme height of such a flood. With the surface of the lake at Elevation 85, corresponding to a bottom level at Elevation 50, as used in estimating the Culebra Cut, the surface area of this lake is 38.5 sq. miles, or about 1 075 000 000 sq. ft. A rise from a depth of 1 ft. to a depth of 5 ft. over the spillway would represent a storage of 4 300 000 000 cu. ft., an average of 50 000 cu. ft. per second for 24 hours, or 25 000 cu. ft. per second for two days. A detailed study shows that, with a discharge of 100 000 cu. ft. per second into the whole basin, the discharge is never likely to exceed 75 000 cu. ft. per second over the spillway, and 5 ft. may be accepted as the variation in the level of the lake. Should a greater flood occur it would merely mean a little higher level in the lake, which might possibly rise to about 6 ft. above the crest of the spillway. Furthermore, the canal through the Culebra Cut would have a cross-section, during this high water, of over 6 000 sq. ft., capable of taking off, at 5 ft. per second, a discharge of 30 000 cu. ft. per second; and the canal north of the Bohio Dam would have a cross-section of not less than 7 000 sq. ft., capable of taking off, at a speed of 3 ft. per second, 21 000 cu. ft. per second.

This general arrangement means a lake the surface of which varies from Elevation 85, when level with the top of the spillway, to Elevation 90, under extreme flood conditions, with a bare possibility of reaching Elevation 91. It involves a spillway at Gigante and a dam at Bohio, of which structures more will be said hereafter. Comparatively little excavation would be required in any portion of the lake, the total between the Bohio Dam and Obispo being barely 2 000 000 cu. yds,, of which, perhaps, one-fourth is rock, and the total cost of which would not exceed $1 000 000.

Below the Bohio Dam the old French location followed the valley of the Chagres about 9 miles to Gatun, where the Chagres turns abruptly to the west and enters the Caribbean Sea some miles west of Colon. This is, perhaps, the only location for a tide-level canal. For 4 miles of this distance the Chagres has absolutely abandoned its old course and flows through the canal. The discharge over the Gigante

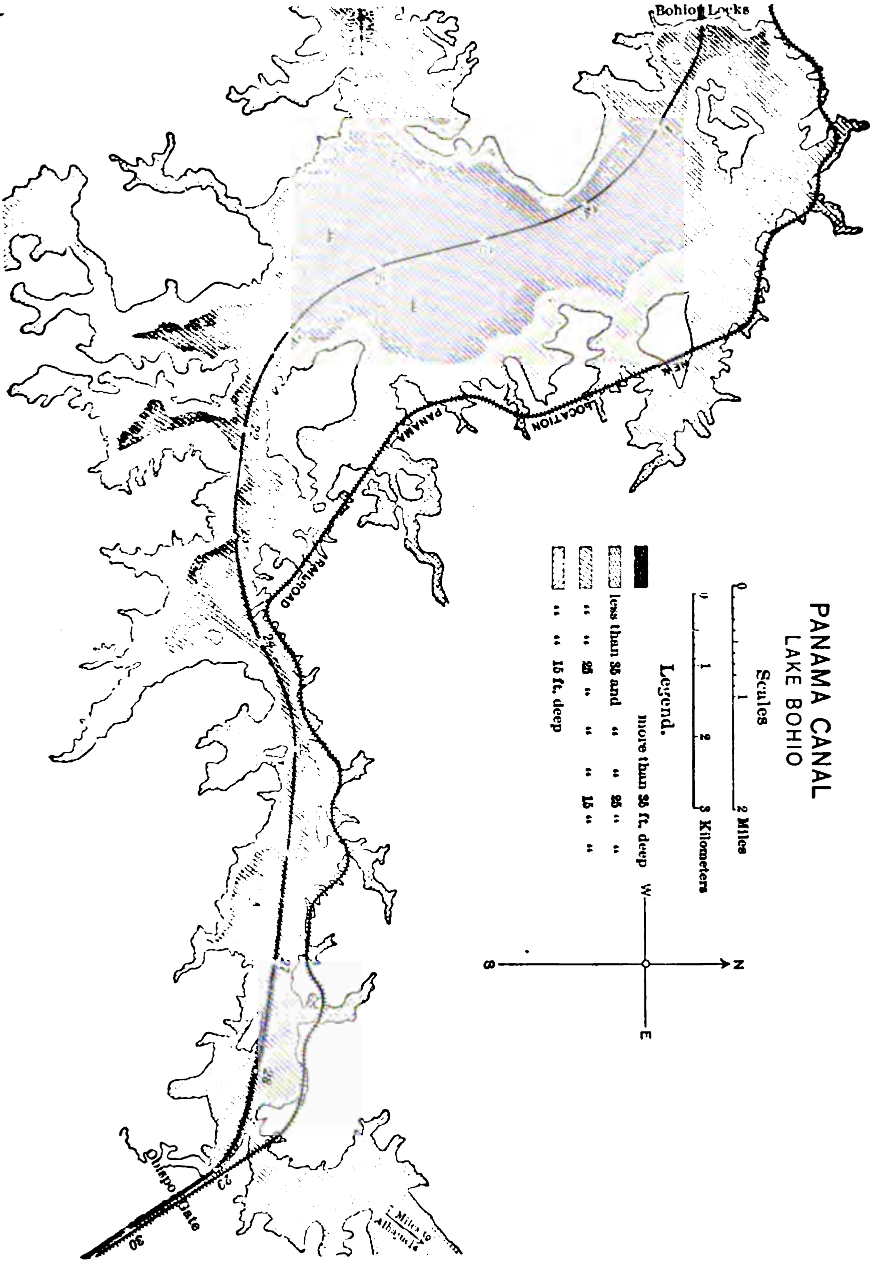

PANAMA CANAL
LAKE BOHIO
Scales
0 1 2 Miles
0 1 2 3 Kilometers
Legend.
▇ more than 35 ft. deep
▨ less than 35 and " " 25 " "
▨ " " 25 " " 15 " "
▨ " " 15 ft. deep
N
S
E
W
Bohio Locks
NEW LOCATION
PANAMA RAILROAD
Obispo Gate
30
Miles to Atlantic

Fig. 1.

Spillway will enter the Chagres about 2 miles below Bohio; below this point one of three courses is practicable. The same course may be adopted that is proposed for a tide-level canal, giving the canal a section of such dimensions that it could pass the flood discharge within its own limits. The valley here is generally comparatively broad, and the floods can be kept out of the canal by constructing a levee on the west side of it; this plan involves a discharge channel between the two swamps, Peña Blanca and Agua Clara, besides which a new channel for the Chagres must be dug across a neck of land opposite Gatun and about three-quarters of a mile from the canal. A location can be adopted east of the Chagres valley, between Bohio and Gatun, by which the canal can be kept a safe distance from the Chagres and for half the way at a safe height above it. This third plan has the advantage of saving 1¼ miles of distance. Furthermore, there is an excellent site for a lock at Tiger Hill, 6 miles from Bohio, by which it is possible to reduce the lift of the Bohio locks. This last line is preferred by the writer, and is used in this description. It is the line shown on the general map, Plate I. The level of the surface of the canal is maintained at 26 ft. above mean tide south of the Tiger Hill lock, the bottom of the canal being 9 ft. below mean tide. The one defect of this plan is that the water is carried a few feet above the level of the surrounding country, but there is such an enormous excess of excavation in the canal that an embankment of almost indefinite width can be built on the river side. This line joins the French location at Gatun, and the new channel for the Chagres opposite Gatun is still necessary.

The problem of the control of the Chagres is absolutely solved by the construction of three works: the Bohio Dam, the Gigante Spillway and the Gatun Diversion.

WATER SUPPLY.

The only source from which a supply of water for the summit level can be obtained by gravity is the Chagres River. The French plan, which contemplated a summit level above that of the lake, proposed to build a dam at Alhajuela and convey the water by a feeder, of complicated design, from the dam to the summit. The same arrangement was proposed by Captain E. P. Lull, U. S. N., in 1875. If the lake itself be made the summit level, any such feeder becomes unnecessary, and the canal will be fed at all times by the Chagres River and the

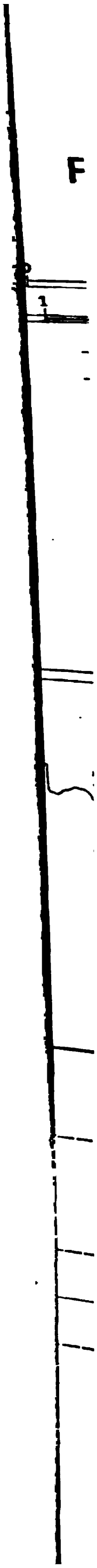
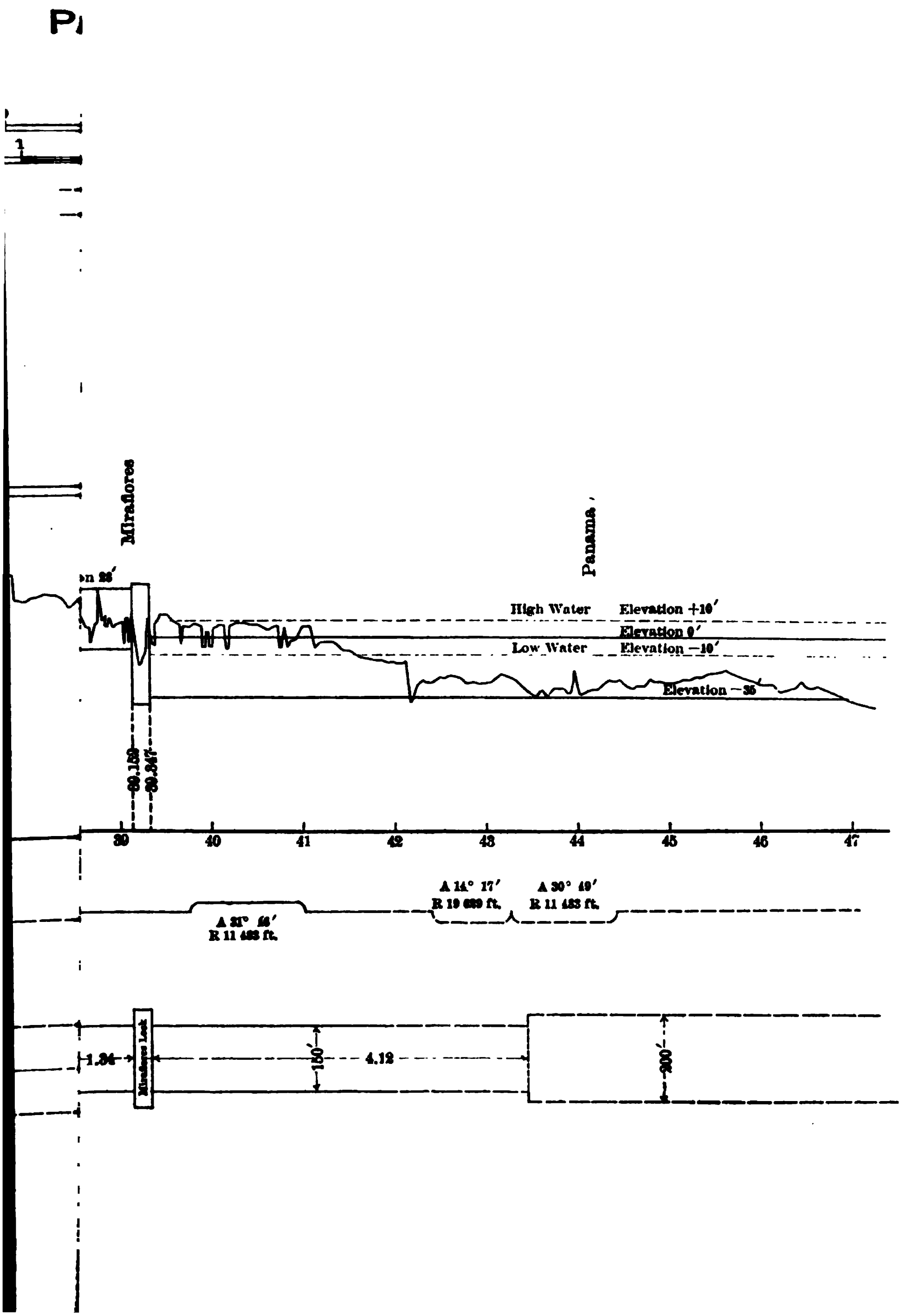
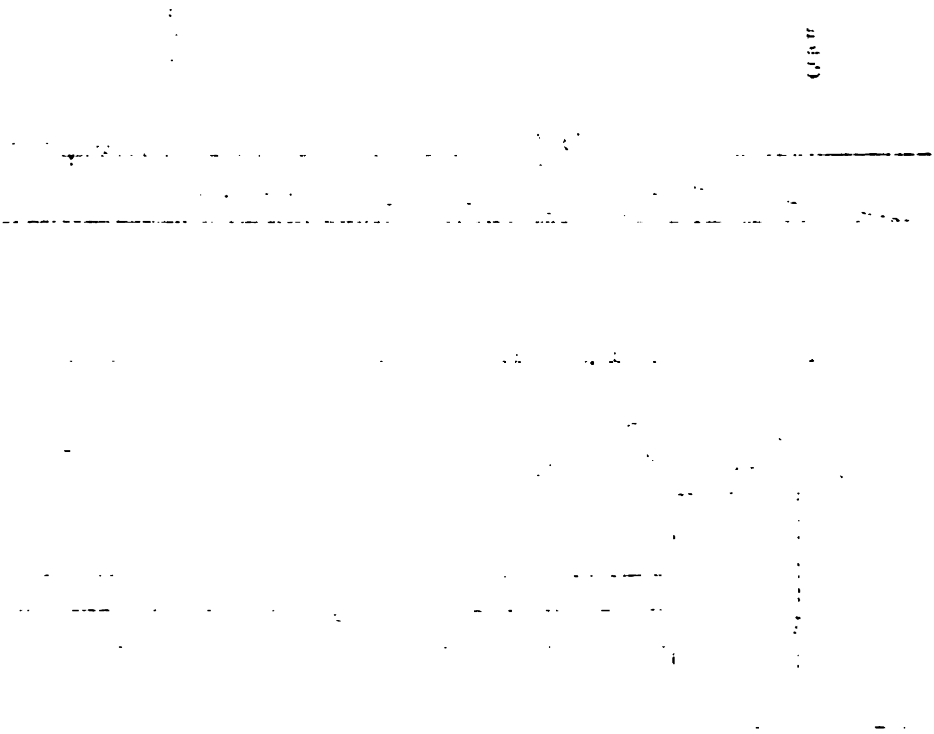


PLATE II.
PAPERS, AM. SOC. C. E.
JANUARY, 1903.
MORISON ON PANAMA CANAL.





various tributaries which are intercepted by the lake. Were the discharge of the Chagres and its various affluents at all times equal to the demands of the canal, no further provision would be required. There is, however, a short period in the early part of each year when the supply is always small and sometimes inadequate. The actual demands for water for canal uses may be limited to three purposes: lockage, seepage and evaporation. Besides this, the French estimates have made provision for power, but this is hardly an actual necessity of the canal, and can be provided in other ways, if the water supply is inadequate. Furthermore, the amount of water actually needed for power is, in the aggregate, exceedingly small.

With the water in the lake at a normal elevation of 85 there will be a descent of 59 ft. to the intermediate level on the Atlantic side, and of 59 ft. to the intermediate level on the Pacific side, an average of 58 ft. Each descent is accomplished by two locks, the average lift of which, in the period when an economy of water is important, is 29 ft. These locks, according to the plan adopted by the Isthmian Canal Commission, are 84 ft. wide and 790 ft. long between gates; each lock chamber contains, therefore, 1 924 470 cu. ft. If it be assumed that ten vessels pass through the canal daily, each using two full locks of water, one ascending and one descending, the total daily consumption will be 38 488 800 cu. ft., or 445 cu. ft. per second. This amount will be reduced materially if intermediate gates are provided in the locks so that smaller vessels can take less than a lockfull of water.

The seepage will be confined principally to the Bohio Dam. There is a short piece of embankment near the Gigante Spillway, but it is of such insignificant dimensions as to be of no importance. Elsewhere, the summit lake is confined between the natural walls of mountain valleys. Estimated on the basis used in the paper on "The Bohio Dam," but with the head reduced to 60 ft., the requirement for seepage would be 28 cu. ft. per second.

To the seepage proper must be added the waste of water the locks. This will depend very largely on gate construction, character of valves, and care of lock tenders. A provision of 200 cu. ft. per second would seem to be ample.

The area of the lake is 38.5 sq. miles, or 1 075 000 000 sq. ft., and the evaporation over this area, taken at 0.5 ft. per month, or 0.0167 ft. per day, or 0.00000019 ft. per second, amounts to 207 cu. ft. per second over the whole area of the lake.

This makes the entire water requirement, with no provision for power, 880 cu. ft. per second. These figures will vary on different assumptions, but it is safe to say that 1 000 cu. ft. per second would be a generous supply for any traffic that is yet in sight. Furthermore, with the tendency to increase the size of ships, it is probable that the actual number of ships will be less, rather than more, than ten daily.

In a general way, it may be said that, out of a total of 1 000 cu. ft. per second, 450 cu. ft. will be required for lockage, 250 cu. ft. for seepage and leakage at gates, and 200 cu. ft. for evaporation, leaving 100 cu. ft. per second for margin and power. This quantity of water, 100 cu. ft. per second, falling 85 ft., will produce about 800 H.-P. on the shaft of a turbine wheel.

The average monthly discharge of the Chagres at Bohio always exceeds 1 000 cu. ft. per second, except during a period of varying length in the months of February, March, April and May. It may have fallen as low as 350 cu. ft. per second for a few days. The French Company has kept daily observations at Bohio of the stage of water for about ten years. From these stages the daily rates of discharge have been calculated, and from these results it is easy to determine the deficiencies, below an average of 1 000 cu. ft. per second, which have occurred during the period of these observations. These deficiencies for nine years are shown in Table No. 1, the last column of which shows the depth of water in the lake corresponding thereto.

TABLE No. 1.

Year.	Cubic feet.	Feet.
1891	2 600 000 000	2.42
1892	291 600 000	0.27
1893	1 166 400 000	1.09
1894	637 000 000	0.60
1895	864 000 000	0.80
1896	648 000 000	0.61
1897	1 728 000 000	1.61
1898	Records incomplete.	
1899	172 800 000	0.16
1900	1 296 000 000	1.21
1901	230 000 000	0.21
1902	0	0.

There are several ways to provide for this deficiency. The first would be to take it from the lake, which has an area of 1 075 000 000 sq. ft.; the last column of Table No. 1 shows that this reduction would still leave it possible for ships drawing 30 ft. at sea to pass through. Another method would be to lower the bottom of the canal through the summit level 3 ft.; this is the plan proposed by the Isthmian Canal Commission; it would add about 1 500 000 cu. yds. to the Culebra Cut, besides increasing the height of the long retaining walls and the cost of the locks; it may be roughly estimated as adding from $2 500 000 to $3 000 000 to the cost of the canal. Another method would be by the construction of the Alhajuela Dam, proposed by the French Company, by which a lake could be formed in the upper Chagres Valley, in which 15 000 000 000 cu. ft. of water could be stored. If the construction of this dam were deferred until after the completion of the other work, so that the lake could be used for transporting material, Elevation 85 carrying still water almost to the site of the dam, the cost of the dam would not exceed the cost of deepening the lake, and it would have the further advantage of storing water above the dam, by which the violence of the floods below the dam would be diminished. A fourth method would be by the use of the old Yankee device of flash-boards, by which the level of the lake could easily be raised 3 ft. above the crest of the spillway, without involving any increase in the height of water during extreme floods. In the judgment of the writer, the canal should be opened with no special provision for additional water supply during the dry months, other than what would be obtained by lowering the level of the lake or by the use of flash-boards. Experience will show what additional storage is required, and, if needed, it can be more economically provided after the other works are completed than before.

Ten lockages each way daily represent the passage of 3 650 ships a year, if no two ships are ever passed together through the same lock at the same time. This would undoubtedly be done occasionally with small vessels. If 10% is added on this account, they represent a passage of 4 000 ships a year, and if these have an average of 2 500 tons, net, they represent a total of 10 000 000 tons yearly. The number of ships passed through the Suez Canal in 1901 was 3 699, the average net tonnage being 2 926 tons. It is probable that the average net tonnage will be at least 4 000 tons when the Panama Canal is opened, and that ten lockages each way daily would represent at least 15 000 000 tons.

It is important, however, to consider the possibilities of water-supply for larger traffic. Of the 1 000 cu. ft. per second required for the wants of the canal, 450 cu. ft. are consumed in lockage. If, therefore, the number of lockages is doubled, representing a passage of at least twenty ships daily, the requirements are 1 450 cu. ft. per second; thirty passages would require 1 900 cu. ft. per second, and forty passages 2 350 cu. ft. per second. The length of time when the discharge of the Chagres falls below these requirements increases with the amounts, but in no instance of which we have any record has it fallen below the maximum requirement of 2 350 cu. ft. per second for a continuous period of more than four months. The deficiencies below these requirements are given in Table No. 2, and are shown in the diagram, Fig. 2.

TABLE No. 2.

Year.	Below 1 450 cu. ft.	Below 1 900 cu. ft.	Below 2 350 cu. ft.
1891	5 437 000 000	9 435 000 000	13 712 000 000
1892	1 069 200 000	2 575 600 000	6 505 900 000
1893	2 760 500 000	5 376 500 000	8 456 700 000
1894	3 164 200 000	6 531 600 000	11 095 700 000
1895	2 140 600 000	5 056 600 000	8 084 900 000
1896	2 708 600 000	5 585 700 000	8 873 900 000
1897	4 060 800 000	7 171 200 000	10 476 000 000
1898	1 555 000 000	3 382 000 000	6 363 000 000
1899	2 702 400 000	5 546 300 000	9 977 900 000
1900	4 523 000 000	8 217 000 000	12 494 000 000
1901	4 900 840 000	8 985 140 000	13 261 940 000
1902	505 400 000	2 605 000 000	5 326 600 000

To meet this deficiency it will be necessary to build a dam at or near Alhajuela. A dam built there, of the height proposed by the French engineers, would form a lake with a total storage capacity of 14 700 000 000 cu. ft. The greatest deficiency (13 712 000 000 cu. ft.) would require a storage of 660 cu. ft. per second for a period of eight months, making the total average requirements for these eight months 3010 cu. ft. per second. The least discharge for eight months, of which there is any record, occurred in 1899 and averaged 4 340 cu. ft. per second, showing that there is ample margin for evaporation and contingencies.

The last supposition provides for 14 600 passages yearly. Before this number of ships is reached it is probable that the average tonnage

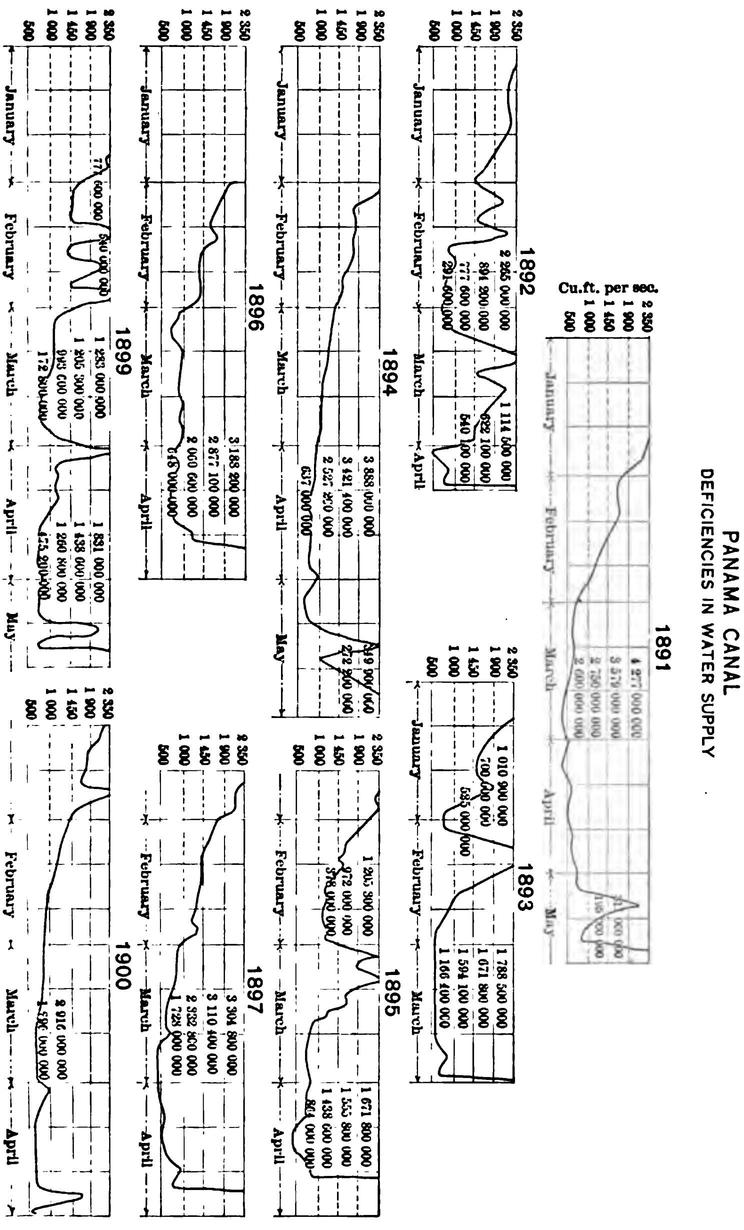

PANAMA CANAL
DEFICIENCIES IN WATER SUPPLY
1891
1892
1893
1894
1895
1896
1897
1899
1900
Cu.ft. per sec.
2 350
1 900
1 450
1 000
500
January
February
March
April
May
4 277 000 000
3 579 000 000
2 750 000 000
2 600 000 000
2 265 000 000
894 200 000
777 600 000
291 600 000
1 114 500 000
922 100 000
540 100 000
1 010 900 000
700 000 000
535 000 000
1 788 500 000
1 671 800 000
1 594 100 000
1 166 400 000
3 888 000 000
3 421 400 000
2 527 200 000
637 000 000
349 900 000
272 200 000
1 205 300 000
972 000 000
378 000 000
1 671 800 000
1 555 800 000
1 438 600 000
894 000 000
3 188 200 000
2 877 100 000
2 060 600 000
648 000 000
3 304 800 000
3 110 400 000
2 332 800 000
1 728 000 000
77 600 000
540 000 000
1 283 000 000
1 205 300 000
993 600 000
172 800 000
1 831 000 000
1 438 000 000
1 260 800 000
475 200 000
2 916 000 000
1 596 000 000

FIG. 8.

will be more than doubled and that this will represent a traffic of from 80 000 000 to 100 000 000 tons annually.

The system now proposed for the control of the Chagres and for the supply of water to the sumit level is entirely automatic, except under two conditions which would very rarely occur. In case of extreme flood, if it is desired to pass any water through the canal, it must be done by opening the lock valves or the gates of a special by-pass. If the Alhajuela Dam is built to make an upper storage reservoir, gates must be opened by which the water will be received from that reservoir; or, if flash-boards are used, those flash-boards must be replaced after floods of exceptional violence, an operation of the very simplest kind. The beauty of the plan recommended is that, in boldly treating the subject as a whole, the annoyance and dangers of detail are avoided.

CULEBRA CUT.

The term "Culebra Cut" is applied by the French Company to the single mile of cutting of greatest magnitude. As used in this paper it is understood to apply to the entire cut between the Chagres valley and the point where tide water is first reached on the Pacific side, the northern terminus of this cut being at Obispo and the southern terminus at Pedro Miguel, a total distance of nearly 8 miles, of which the southern 2 miles are in a comparatively low country. For 5 miles this cut is really through a mountain, the maximum original height, on the center line of the canal, being 330 ft. above mean tide. While in the upper part of the work where the cut was first opened there is some soft and slippery clay, nearly the whole of this excavation must be made through a material which has generally been rated as rock. It is, in fact, an indurated clay, not firm enough to class as shale, but perhaps quite as hard to work. It is intersected here and there by thin strata and dikes of hard limestone. It is a material which would weather rapidly and go to pieces in a northern climate where there is frost; in the damp warm climate of the Isthmus it does better, but when fragments are immersed in water they fall into powder, and it would evidently be unsafe to expose the unprotected sides of this excavation to the wash of the water in the canal. It was the judgment of the Commission, in which the writer fully concurs, that this cut should be estimated on the basis of slopes of 1 on 1, which is a little flatter than the slope adopted by the new French Company. This does not mean that the cut would be excavated to those lines. The plan selected by the French Company, consisting of a number of benches connected by comparatively steep slopes, is probably the best way to finish the sides of the cutting, but it was thought that an estimate based on uniform slopes of 1 on 1 would give aggregate results quite as close to the actual work as could be obtained by more complicated calculations; furthermore, it would probably leave a margin to cover such special repairs as may be found necessary where faults and weaknesses appear on the slopes. On the basis of 150 ft. bottom width and slopes of 1 on 1, this cut, 7.95 miles long between Obispo and Pedro Miguel, with the bottom at an elevation of 47 ft. above mean tide, was estimated by the Isthmian Canal Commission to contain 43 237 000 cu. yds. With the depth remaining constant, each foot of increased or decreased width would represent, approximately, 150 000 cu. yds., provision being made for retaining the full width at a passing point, 1 600 ft. long, near the middle of this section. As the side slopes are 1 on 1, the bottom width being constant, each foot that the bottom is raised or lowered would represent an approximate decrease or increase of 300 000 cu. yds., besides the bottom excavation above or below Elevation 47. If the bottom were raised 3 ft., to Elevation 50, it would save 1 600 000 cu. yds., reducing the volume to approximately 41 600 000 cu. yds. If the width of this cut were reduced from 150 to 100 ft., this would represent a further approximate saving of 7 500 000 cu. yds.

On the other hand, if the bottom of the canal were lowered to 35 ft. below mean tide, the bottom width being reduced to 100 ft., reverting to the original de Lesseps scheme for a tide-level canal, the amount of excavation in crossing the divide would be increased to about 85 000 000 cu. yds. While this quantity is enormous, it is not beyond the capacity of a well-conducted work.

The concentration of so large an amount of excavation in so small a distance is without precedent. The engineer will recognize at once that it requires thorough organization, and tools specially adapted to the work. The large plant provided by the old French Company is now from fifteen to twenty years old. Those years have been years of unusual development in this class of machinery. Time is of the utmost importance. The wisest course would be to consign practically everything which is now on the Isthmus to the scrap heap, and handle this work with the best modern tools that can be obtained; some of these might be tools which could be bought in the market, but many must be specially designed for this particular work. Fortunately, there is ample ground on which to deposit the spoil from this great cut both north and south of the divide, but the manner of conducting the work, both in general principles and in detail, should be thoroughly worked out before actual execution is begun. No work has ever been undertaken on which the highest class of practical engineering talent could produce so great economies as in this particular great concentrated excavation. The Isthmian Canal Commission estimated the cost of this excavation at 80 cents per cubic yard; bad management would quickly raise this to a dollar, and it is not impossible that with a carefully considered equipment the cost could be reduced to 60 cents. In this single cut $25 000 000 is an easy measure of the difference between competent and incompetent management.

As already stated, it is thought unsafe to allow the earth in this cut to be washed by the water of the canal. The French plans have recognized this and have provided for facing the slopes of the canal with masonry. The construction of this cut interferes with the old line of the Panama Railroad. With the canal completed, the railroad will have little value except as a tender to the canal, and its most convenient location would be close to the canal. It is important to provide broad benches between the water of the canal and the slopes of the cut, so that any material which may break loose on the slopes can be stopped and handled before it reaches the water of the canal. It is desirable, if the sides of the canal are lined with masonry, to have this masonry nearly vertical, so that there would be no danger of a ship striking the masonry lining below water. These requirements are met by a special cross-section, which is shown in Fig. 2. The masonry walls may appear unnecessarily expensive, but their function is triple—they protect the slopes from the wash of the water; they accommodate the Panama Railroad; and they provide a bench in case of accident on the slopes. These walls should be provided for a length of 32 000 ft.—about 6 miles. They would contain in the aggregate 1 200 000 cu. yds. of concrete masonry, and their length and cost is practically independent of the elevation of the canal bottom or the width of the canal.

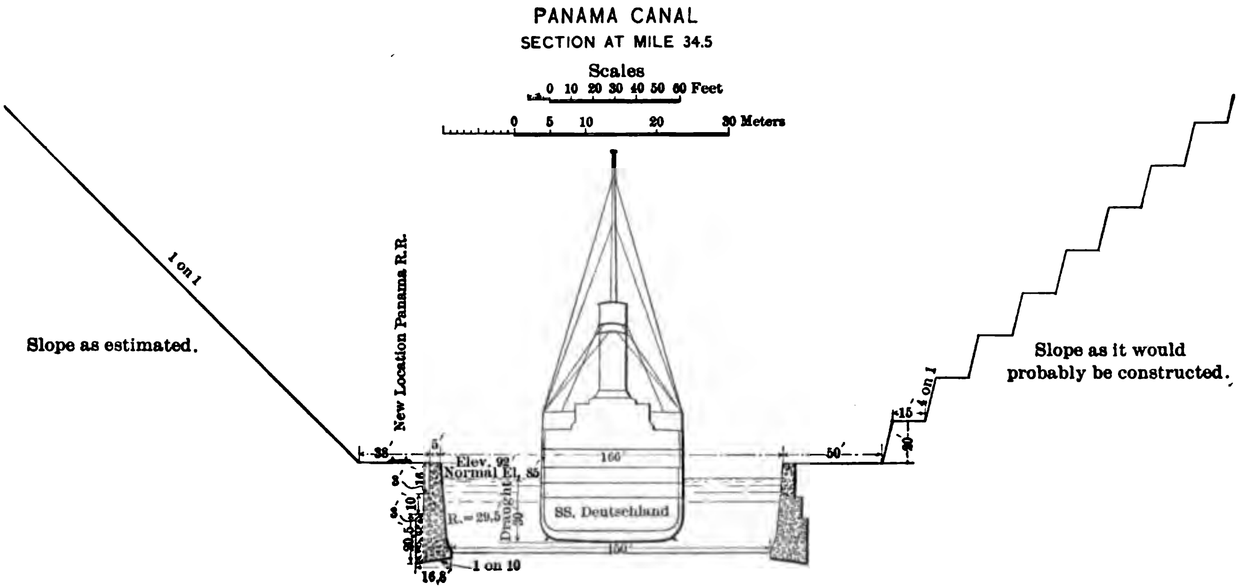

PANAMA CANAL
SECTION AT MILE 34.5
Scales
0 10 20 30 40 50 60 Feet
0 5 10 20 30 Meters
Slope as estimated.
1 on 1
New Location Panama R.R.
38'
5'
Elev. 92'
Normal El. 85'
8'
16'
10'
8'
20.5'
R. = 29.5
Draught 30
166'
SS. Deutschland
150'
1 on 10
16.8'
50'
20'
15'
4 on 1
Slope as it would
probably be constructed.

Fig. 8.

Combining these two results and using the price of 80 cents per cubic yard for excavation and $8 per cubic yard for concrete masonry, we have as an approximate estimate of the cost of this cut, with a bottom width of 150 ft. at Elevation 50, $43 000 000. Each foot of increased width will represent an additional cost of $120 000, and each foot that the bottom may be lowered will represent an additional cost of about $400 000.

A tide-level canal 35 ft. deep, with a bottom width of 150 ft. between Obispo and Pedro Miguel, would cost nearly $90 000 000.

INTERMEDIATE LEVELS.

There would be two intermediate levels—a level 5.58 miles long between the Bohio and Tiger Hill locks on the Atlantic side, and a level 1.27 miles long between the Pedro Miguel and the Miraflores locks on the Pacific side.

The former may be designated as the Tiger Hill Level and the latter as the Miraflores Level.

The normal surface of the water in the Tiger Hill Level is at Elevation 26, the bottom of the excavation being at Elevation — 9. This level involves nearly 8 000 000 cu. yds. of excavation, of which about one-third would be rock. Its estimated cost is about $5 000 000. For a portion of the distance the water in the canal is carried above the level of the surrounding country, and it is carried across the bed of the Chagres three times, twice at places where that bed is already abandoned, and once at Bohio, where the river will continue to flow until the discharge of the lake through the Gigante Spillway is accomplished. No complete borings have yet been taken along this line of the canal, but the indications are that no serious trouble is to be expected, the only possibility being leakage, which can be controlled by a moderate amount of puddling.

The normal surface of the water in the Miraflores Level is at Elevation 28, the bottom of the excavation being at Elevation — 7. This level is perfectly straight, and involves only 1 200 000 cu. yds. of excavation, of which one-quarter may be rock. The estimated cost is $800 000. This section is really the deepening of a natural valley, and the surface width of the water will exceed that of the canal proper. A small fixed dam, which will act as a spillway, will be required adjoining the Miraflores Lock.

MARITIME LEVELS.

The Atlantic Maritime Level will be 9.33 miles long, from the 6-fathom contour in Colon Harbor to the Tiger Hill lock, of which seven-tenths of a mile will be outside the terminus of the French Canal. The difficulties of the 35-ft. channel are more marked here than at any other place. Colon Harbor practically lies entirely within the 6-fathom contour, so that the channel has to be extended from the terminus proposed for the French Canal completely through the harbor to deep water. It is probable that a considerable amount of coral rock will be met in excavating this line to deep water, although the exact amount is not known. The cost of the channel outside the terminus of the French Canal, excavated with a bottom width of 500 ft., was estimated by the Isthmian Canal Commission at $1 284 270. This work could be deferred until after the opening of the canal, but it must be done before the largest class of vessels can be accommodated. Very careful and full surveys must be made of this portion of the bay before the best location for this deep-water channel can be determined, and it is possible that it may be found best to cut through the artificial point on which the statue of Christopher Columbus now stands, making the terminus of the canal near the northern end of Colon, at which point some kind of protective breakwater may then be required. The 8.92 miles of canal proper, from the terminus of the French work, opposite the statue of Columbus, to the Tiger Hill lock, would involve an excavation of 14 761 669 cu. yds., this including an allowance for an inshore basin, and is estimated to cost $9 813 000, making the approximate cost of the entire maritime section $11 100 000, of which $1 300 000 can be deferrred until after the opening of the canal.

The Pacific Maritime Section is 8.60 miles long from Miraflores lock to the 6-fathom contour in Panama Bay. Of this, 5.50 miles are canal proper, through a very low country, and the remaining 3.10 miles are open channel, through Panama Bay. This section involves the excavation of nearly 7 000 000 cu. yds., of which about one-fifth would be rock under water—the most expensive kind of excavation—and the remainder hydraulic dredging—the very cheapest kind of excavation. The estimated cost of this level is somewhat less than $8 000 000.

The description already given of the Tide-Level Canal has included the line through to deep water in the Atlantic. On the Pacific side, the work between the Miraflores lock and the 6-fathom contour would be identical with that of the high-level canal. The Miraflores lock would be required as a tide lock. The Miraflores Level would be lowered 28 ft. The excavation on this level would be, approximately, 2 500 000 cu. yds., at a cost of, approximately, $2 500 000, a portion being rock under water.

SPECIAL STRUCTURES.

If the tide-level canal were adopted, but two special structures would be required—a tide lock at Miraflores and a dam at Alhajuela, the object of the dam being simply to check the flow of extreme floods, and its construction could be deferred until the completion of the canal. The lock at Miraflores would be fitted with double gates and used strictly as a tide lock. In cases of extreme floods the gates should be kept closed at all times, so as to prevent any undue current through the summit cut. Under ordinary conditions it might be expedient to leave all the gates open when the tide is above mean stage, thus allowing a moderate current to flow from the Pacific to the Atlantic during high tide. The exact working of such a lock would, however, be determined by experience. The approximate cost of the lock and the Alhajuela Dam, including a railroad to the dam site, may be taken at $8 000 000.

On the high-level canal there would be six important constructions, besides five other works of less size. These eleven constructions are as follows:

1.—Bohio Dam;
2.—Gigante Spillway;
3.—Bohio Locks;
4.—Pedro Miguel Locks;
5.—Tiger Hill Lock;
6.—Miraflores Lock;
7.—Obispo Gates;
8.—Tiger Hill Spillway.
9.—Miraflores Spillway;
10.—Diversion Channel near Gatun;
11.—Diversion of Panama Railroad.

Bohio Dam.—The summit level is sustained by the Bohio Dam, although its height is regulated by the Gigante Spillway. The situation of the dam, about 3 miles away from the spillway, is very important. The functions of the dam are confined to holding back the water, the dam never being exposed to any currents, either above or below, and the only source of danger being wave action and possible infiltration. The plan of dam which the writer prefers is described in the paper on "The Bohio Dam."* Since that time his attention has been called to a form of metallic sheet-piling, designed and used by Mr. George W. Jackson, of Chicago, composed of channels and I-beams, which seems to admit of penetration to very great depths, and may form an inexpensive and available method of absolutely closing the seepage through the valley, should such closure be considered sufficiently important. This arrangement of sheet-piling is shown in Fig. 4.

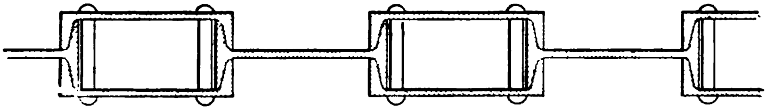


FIG. 4.

Gigante Spillway.—The Gigante Spillway, although a work of considerable magnitude, involves no special difficulties in construction, as rock is found for its entire length above tide-water level. It would be built in the form of a masonry dam with a crest 2 000 ft. long. The estimated cost of this spillway is $1 200 000, this including the excavation for the foundation and such excavation as is necessary to make a clear approach for the water from the lake.

Locks.—There will be four sets of locks, of which two, at Tiger Hill and Miraflores, have a single lift; and two, and Bohio and Pedro Miguel, a double lift. It is proposed to build twin locks in every case, so that an accident to a single lock would not close the canal to traffic. The construction of the second lock would, however, be properly deferred until after the opening of the canal. This arrangement requires twelve lock chambers, in all.

The plan of the French engineers involved sixteen lock chambers, which they estimated to cost 137 000 000 francs, or 8 562 500 francs per chamber—in round numbers, $1 700 000 per lock chamber.

The Isthmian Canal Commission, estimating on the line now recommended, made the cost of the locks $29 189 994, an average of $2 432 500 per lock chamber.

**Transactions*, Am. Soc. C. E., Vol. xlviii, p. 235.

It is probable that a considerable saving could be made by using metal in combination with the concrete of the locks, but, for present purposes, the estimate of the Isthmian Canal Commission may be accepted, and the cost of the locks given in round numbers as $29 000 000, of which about $17 000 000 would represent the cost of the first set of locks and $12 000 000 the cost of the second or twin locks.

Obispo Gates.—Conditions can be conceived of in which it will be important to draw off the water from the Culebra Cut without disturbing the water in the lake. For this purpose a pair of gates should be placed at the north end of the cut. These gates, if made 100 ft. wide, with the necessary masonry and excavation, are estimated to cost $300 000.

Tiger Hill and Miraflores Spillways.—Two spillways are required, one adjoining the Tiger Hill lock and the other adjoining the Miraflores lock, to take care of excess water in the intermediate levels. These are small affairs, the estimated cost of the two being less than $100 000.

Diversion Channels.—The principal diversion channel required will be that across the peninsula opposite Gatun; this would be a cut of considerable magnitude, and much of it would be through rock. It has been estimated of sufficient size to give a cross-section of 10 000 sq. ft. In addition to this the diversion channel dug along the east side of the canal by the old French Company must be put in order to take the discharge of the Gatun and the various other local streams which would otherwise enter the canal. An allowance of $2 000 000 should be made for these works, nearly all of which will be for the Chagres Diversion.

Diversion of Panama Railroad.—Both tide-level and high-level canals interfere with the Panama Railroad, the latter much more than the former.

For the canal described in this paper, the location of the Panama Railroad will have to be changed for a short distance near Tiger Hill and for the entire distance between Bohio and Obispo, while from Obispo to Pedro Miguel the railroad would be carried through the cut made for the canal. The cost of these changes in the Panama Railroad is estimated at $1 300 000.

The tide-level canal interferes but little with the Panama Railroad;

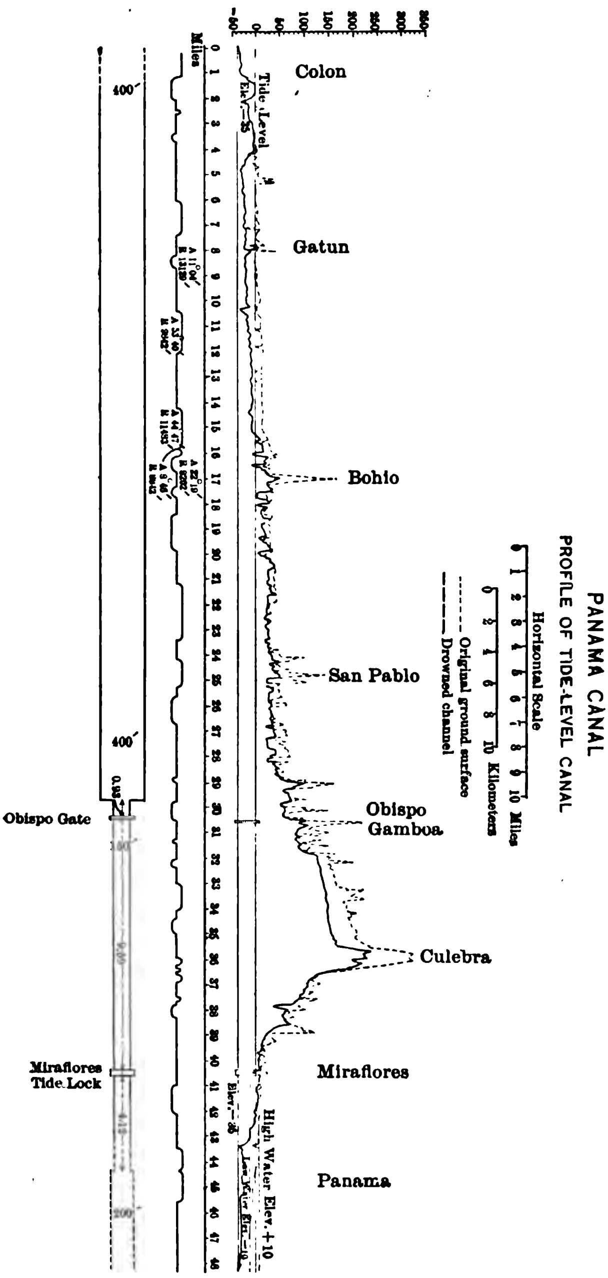

PANAMA CANAL
PROFILE OF TIDE-LEVEL CANAL
Horizontal Scale
0 1 2 3 4 5 6 7 8 9 10 Miles
0 2 4 6 8 10 Kilometers
Original ground surface
Drowned channel
Colon
Gatun
Bohio
San Pablo
Obispo
Gamboa
Culebra
Miraflores
Panama
Tide Level
Elev. −35
High Water Elev. +10
Low Water Elev. −10
Miles
400′
400′
Obispo Gate
Miraflores
Tide Lock

FIG. 5.

but, in order to avoid crossing the canal, a new line of railroad should be constructed from San Pablo to Obispo, about 6 miles, and the railroad should be carried through the cut between Obispo and Pedro Miguel; these changes would probably not cost more than $500 000.

ESTIMATES.

The estimates made in this paper are based on the report of the Isthmian Canal Commission, modified to suit changes in plans. In general, round figures have been taken, as it seems unwise to confuse the memory with a number of small figures, which measure less than the margin of error. By combining the figures already given in detail we have the approximate total cost of the two classes of canals.

To the figures so obtained, an addition has been made of 20% to cover the various incidental expenses and contingencies. The incidental expenses are understood to include engineering, policing and sanitation; in fact, all the expenses on the Isthmus which would not be borne by the contractors. They are not supposed to include any expenses of a home office or of interest during construction. This percentage is double that usually applied in estimating the cost of work in settled countries where risks are not unusual.

Tide-Level Canal.—The cost of a canal on this plan would be approximately as given in Table No. 3.

TABLE No. 3.—COST OF TIDE-LEVEL CANAL.

Chagres Section, Colon to Obispo..........	p. 21	$90 000 000
Culebra Section, Obispo to Pedro Miguel...	p. 34	90 000 000
Miraflores Section........................	p. 36	2 500 000
Pacific Maritime Section..................	p. 35	8 000 000
Miraflores Lock...........................	p. 36	5 000 000
Alhajuela Dam and Railroad...............	p. 36	3 000 000
Diversion of Panama Railroad.............	p. 40	500 000
		$199 000 000
Engineering and Contingencies, 20%.............		39 800 000
Total.............................		$238 800 000

Nearly the entire cost of this canal will be for excavation.

Lock Canal.—The estimated cost of a canal with locks, as described in this paper, the summit level varying from 85 to 90 ft., with three locks on each side, six in all, will be as given in Table No. 4.

TABLE No. 4.—COST OF LOCK CANAL.

Atlantic Maritime Level, Colon to Tiger Hill	p. 35	$11 100 000	
Tiger Hill Level	p. 34	5 000 000	
Lake Bohio	p. 22	1 000 000	
Culebra Cut	p. 34	43 000 000	
Miraflores Level	p. 34	800 000	
Pacific Maritime Level	p. 35	8 000 000	
			$68 900 000
Bohio Dam	p. 36	$2 000 000	
Gigante Spillway	p. 37	1 200 000	
Locks	p. 37	29 000 000	
Obispo Gates	p. 38	300 000	
Tiger Hill and Miraflores Spillways	p. 38	100 000	
Diversion Channels	p. 38	2 000 000	
Diversion of Panama Railroad	p. 38	1 300 000	
			35 900 000
			$104 800 000
Engineering and Contingencies 20%			20 960 00
Total			$125 760 000

The cost, therefore, of completing the Panama Canal on the lock plan would be about one-half that of completing it on the tide-level plan. This, however, does not tell the whole story. Neglecting the percentages for contingencies, all but $18 000 000 of the $199 000 000 estimated for the tide-level canal is for excavation. Of the $46 000 000 estimated as the cost of the Culebra Cut, in the high-level canal, $9 600 000 is for retaining walls along the sides of the cut; this reduces the cost of excavation to $59 000 000, or approximately three-fifths of the total cost of the canal (percentages still being omitted). In other words, although the cost of the tide-level canal is only about double that of the lock canal, the cost of excavation in the tide-level canal is about three times the cost of excavation in the lock canal. Excavation represents work which must be done entirely on the Isthmus. Much of the cost of special structures represents material which would be manufactured elsewhere. If it be assumed that one-half the cost of the special structures represents work on the Isthmus, it may be said, in a general way, that four-fifths of the cost of the lock canal and the whole cost of the tide-level canal will represent work on the Isthmus. As the tide-level canal will cost twice as much as the lock canal, the amounts to be expended on the Isthmus for the two canals will be approximately as five is to two. The number of workmen required on the Isthmus, as well as the time required to complete the work, will be determined by these conditions.

The tide-level canal will have to be completed before it can be opened to traffic, the only postponement being in a portion of the cost of the special structures, which is insignificent. The lock canal can be opened with the second set of locks unfinished, and before the channel in Colon Harbor is deepened. This will reduce the expenditures required before opening the canal to about $92 000 000, without the percentage, or to a total of $110 000 000.

These estimates are based on the conditions now existing at the Isthmus, advantage being taken of the work which has been done there by the French and of the Panama Railroad. The work done by the New Panama Canal Company is practically all effective. Much of the work done by the old company is valueless. The canal which was excavated through the low country was taken out with a bottom width of 22 m. and a depth of 9 m., and the material was wasted close to the banks. To construct a canal of the increased dimensions now required will involve rehandling the spoil banks. Furthermore, the plan proposed in this paper would utilize the canal between Gatun and Bohio only as a channel for the Chagres, for which purpose it is of great value. The value of all this work, including the railroad, was estimated by the Isthmian Canal Commission at $40 000 000, which sum the New Panama Canal Company of France, and the official liquidator, representing the shareholders and creditors of the defunct Universal Interoceanic Canal Company, have agreed to accept as the price for which they will deliver everything they now own on the Isthmus, together with their records, maps and other papers. If this is added to the foregoing estimates, the cost of the tide-level canal would be about $280 000 000 and that of the high-level canal $166 000 000, exclusive of interest during construction.

Conduct of Work.

The first thing to do is to clean up the Isthmus, to provide sewers where feasible, and sanitary rules everywhere, to furnish the entire line with good water, of which a great abundance may be had at moderate expense, and to compel the employees on the canal to drink nothing else. This will take at least a year.

The plans made by the New Panama Canal Company were unusually complete for any preliminary work of this kind, but they were for a canal of different dimensions, with many details which would not be acceptable to American builders. The plans and examinations of the Isthmian Canal Commission were made for purposes of comparison and preliminary work rather than for actual construction. The final working designs remain to be made. Specifications must be prepared and all the necessary preliminaries which precede the letting of so great a work completed. Both the home and local organizations must be perfected. Much of this work can be done simultaneously with the sanitary preparations, and will take as long. A year spent in preparation, before the contracts are let, will save time in the end.

After the contracts are awarded, the contractors should be allowed another year to perfect their preparations. This is little enough time to provide for the organization of their forces and the purchase and collection of their machinery, much of which will have to be made after the contracts are awarded.

In two years after the transfer of the French property and the beginning of American occupation, actual construction work should fairly begin. The one greatest single piece of work is the Culebra Cut, and the time required to complete this cut will be the time which it will take to build the canal. All other work should be laid out with reference to this, so that, when it is completed, there will be no unfinished work to delay the opening of the canal.

The bulk of the laborers must be West Indian negroes, from Jamaica and perhaps some other islands. Skilled labor must come from the North, and generally be white. The methods of work should be so designed that the number of skilled workmen shall be as small as possible, and that they shall be protected from rain and sun when at work. It will probably be expedient to use electric power instead of steam as far as possible. A dam at the site of the Alhajuela Dam would furnish the power. If electric shovels could be used instead of steam shovels, but one skilled man, instead of two, would be required at each shovel, and the heat from the boiler would be avoided. The debilitating influences of the damp, warm climate remain, and a system of furloughs must be arranged which will permit the white employees to recuperate in northern climates at least once a year.

The French companies were private corporations, working with no greater powers than those derived from their concessions. All this will be changed when the work becomes a Government undertaking. The powers of the United States will be those of military occupation, under which a sanitary control and discipline can be exercised, which should remove the greatest difficulties which have hitherto beset the Isthmus of Panama.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

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PAPERS AND DISCUSSIONS.

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A HIGH-VOLTAGE POWER TRANSMISSION.

By M. H. Gerry, Jr., Assoc. M. Am. Soc. C. E.

To be Presented March 4th, 1903.

Introduction.

In 1891 the Missouri River Commission, United States War Department, completed a survey of the Upper Missouri River, including triangulation, topography, hydrography and check levels. The records of this survey for the first time made available complete engineering information regarding the Upper Missouri River. From Three Forks to a point below Canyon Ferry the field work was under the direction of Mr. G. A. Marr, Assistant Engineer, and was fully reported by the Commission in 1891.* The river was then considered navigable to Three Forks, where the main stream is formed by the confluence of the Madison, Jefferson and Gallatin Rivers. From Three Forks to Canyon Ferry, the present location of the dam, the distance along the channel is about 81 miles. The watershed above Canyon Ferry is about 15 000 sq. miles in extent, comprising large parts of Madison, Beaverhead, Gallatin, Jefferson, Silver Bow, Lewis and Clarke, Meagher, and Broadwater Counties, of Montana, and the Yellowstone

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* Annual Report of the Missouri River Commission, being Appendix AAA of the Annual Report of the Chief of Engineers, U. S. A., for 1891.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

National Park. It is nearly all mountainous country, and embraces slopes of the Big Belt and main range of the Rocky Mountains, as well as a number of smaller ranges.

As the result of action by the Board of Trade of the City of Helena, an investigation was ordered by the United States War Department, and a report made on May 10th, 1892, by Captain Charles F. Powell, to the Chief of Engineers, United States Army, pointing out that no regular navigation existed above Great Falls, Montana, and stating that the construction of dams was feasible at a number of points on the Missouri River near Helena. An Act of Congress (approved July 13th, 1892) provided for a more extensive examination of the Missouri River from Three Forks to Canyon Ferry, with a view to determining at what points water-powers could be developed for manufacturing and other purposes. The examination thus authorized was made in 1893 by Mr. Edwin D. Vincent, Assistant Engineer, and the results of his investigation were reported by Captain H. F. Hodges, on January 22d, 1894, to the Chief of Engineers, United States Army. This report contained much valuable information, and indicated, especially, several practicable locations for dams.*

The Helena Water and Electric Power Company was organized, under the laws of the State of Montana, in May, 1896, and work was commenced on the dam at Canyon Ferry the following July, under the direction of Mr. Hugh L. Cooper, Resident Engineer, and J. T. Fanning, M. Am. Soc. C. E., Consulting Engineer. The original intention of the promoters of this enterprise was to supply electrical power and water for manufacturing, private and public purposes, to the City of Helena. About the time the work was begun, Mr. Barton Sewell became General Manager, and Mr. C. W. Whitley, Superintendent. A timber-crib dam, designed by Mr. Fanning, was completed in March, 1898, and the construction of a stone power-house to contain four units, together with the necessary penstocks, gates, etc., was well under way. It was at this time that the property came under the direction of the writer as chief engineer. The plant was completed on the original lines, and consisted of four generating units, each comprising a two-phase alternating-current generator of 750 kilowatts, directly connected to a pair of horizontal water-wheels.

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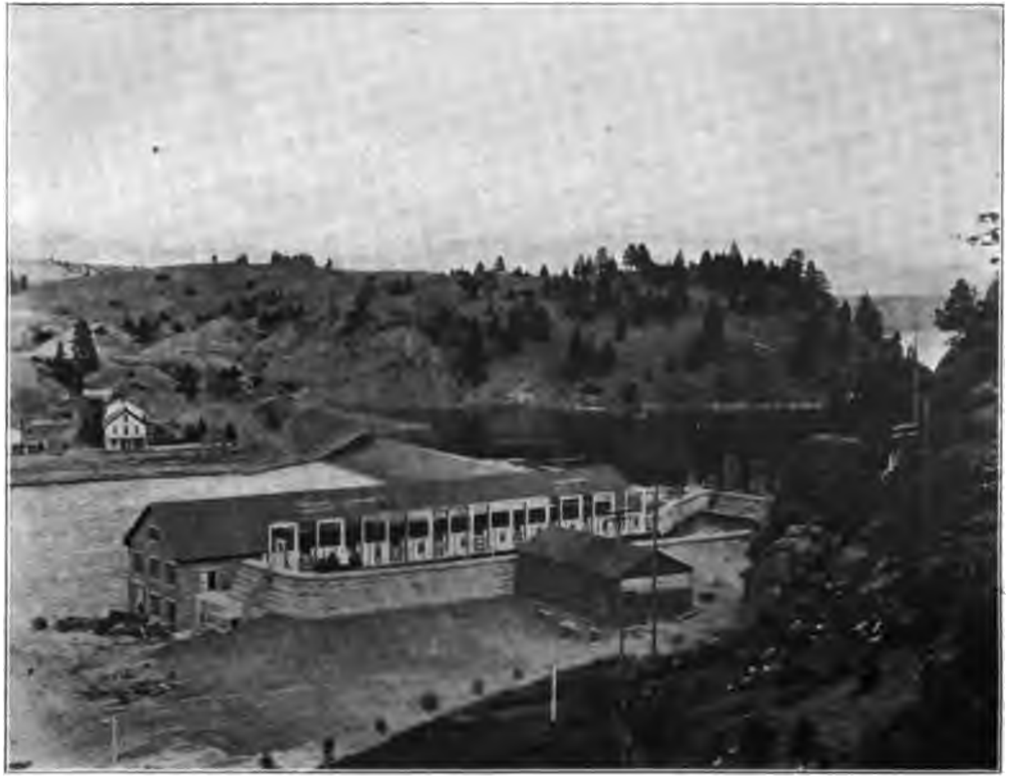
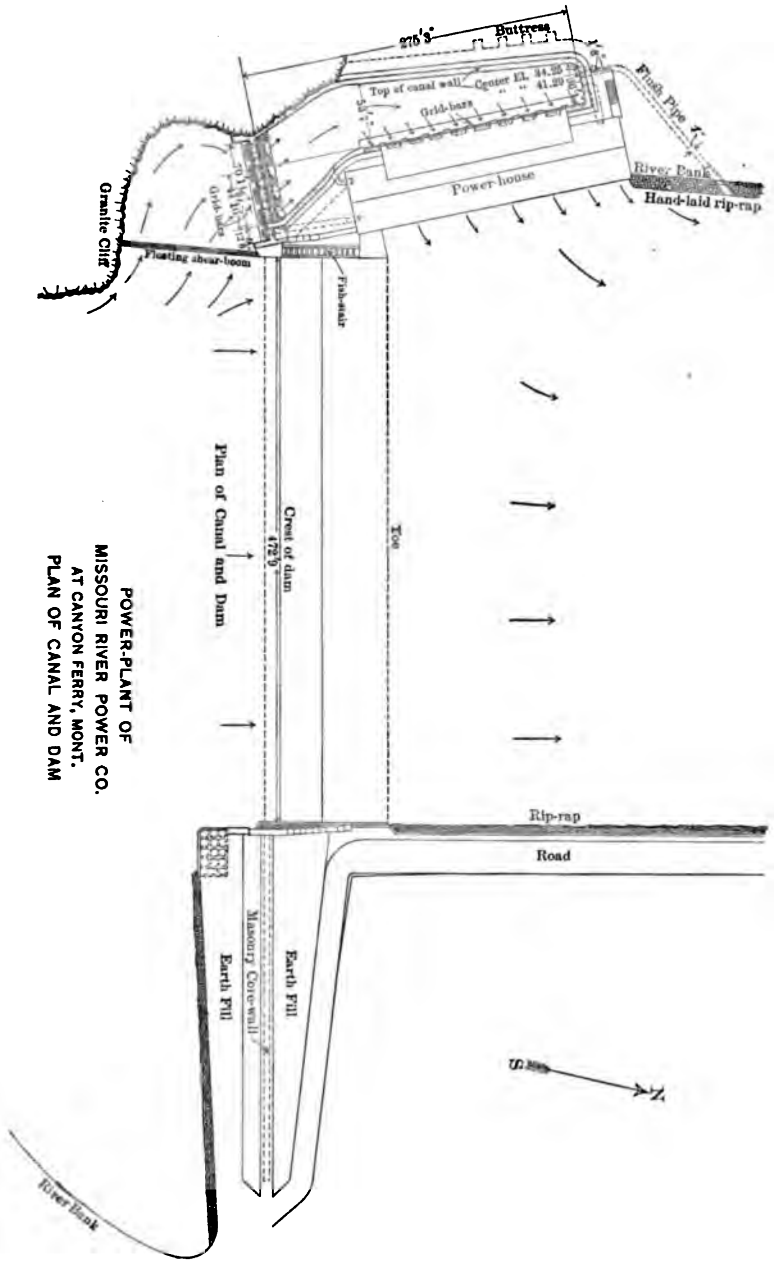
* House of Representatives, Executive Document No. 96, 53d Congress, Second Session, Letter from the Secretary of War, transmitting Report of the Examination of the Missouri River from Three Forks to Canyon Ferry, Montana.

PLATE III.
PAPERS, AM. SOC. C. E.
JANUARY, 1903.
GERRY ON POWER TRANSMISSION.

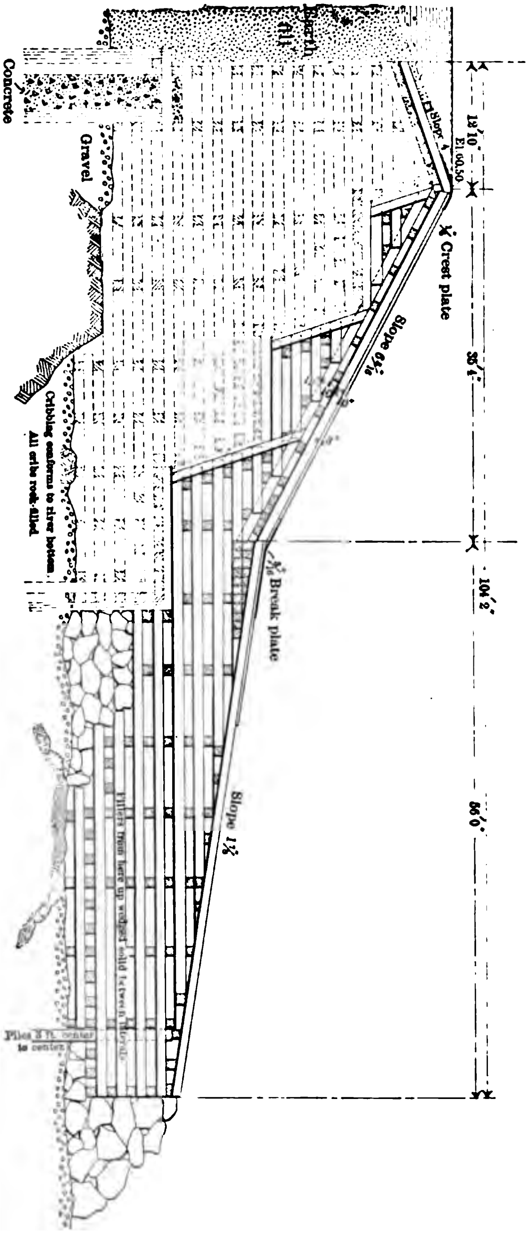


Canyon Ferry Dam, Power-House and Canal.



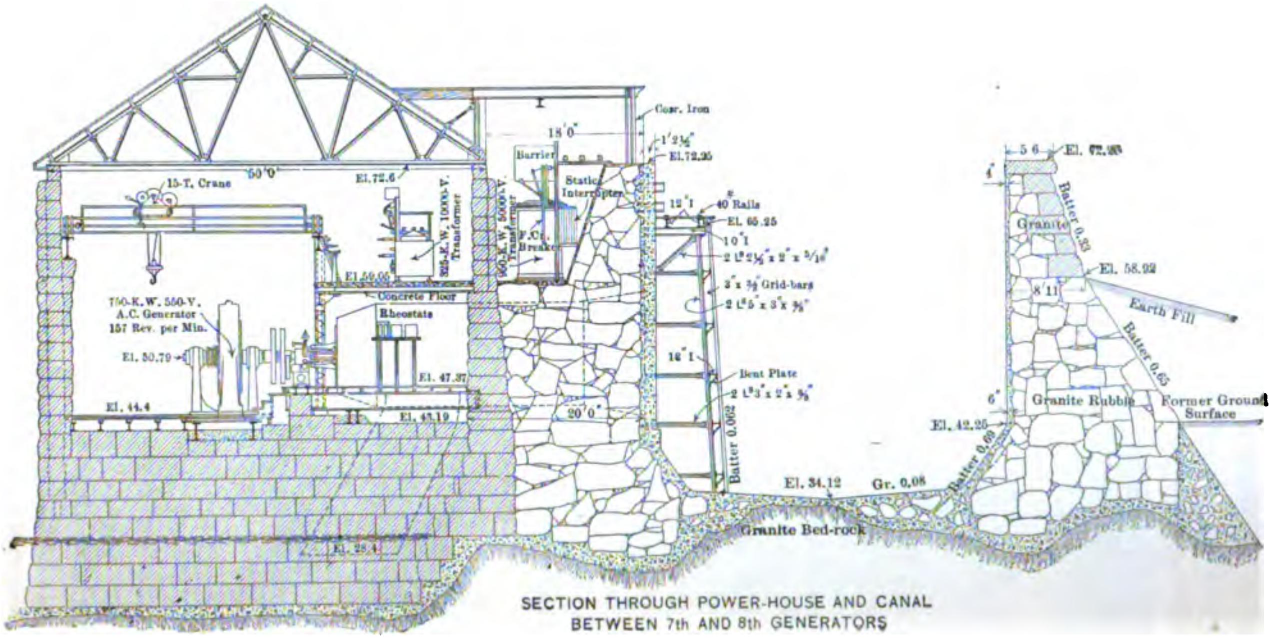
POWER-PLANT OF
MISSOURI RIVER POWER CO.
AT CANYON FERRY, MONT.
PLAN OF CANAL AND DAM

FIG. 1.



CANYON FERRY DAM
AS RECONSTRUCTED

FIG. 2.



SECTION THROUGH POWER-HOUSE AND CANAL BETWEEN 7th AND 8th GENERATORS

FIG. 8.

Water was supplied to the wheels through two steel penstocks, 12 ft. in diameter, from a forebay excavated in the solid rock above the dam.

In May, 1898, shortly after the completion of the dam, and before the remainder of the plant was ready for service, the dam was damaged to some extent by extreme high water. It was immediately repaired and reconstructed on somewhat different lines, and since then has given no trouble. A complete electrical transmission system, operating at 12 000 volts, was installed, and a pole-line constructed to Helena by way of East Helena, together with several branch lines to near-by points. The plant went into regular service in October, 1898, supplying, from the first, three large customers: The East Helena Smelter (now the property of the American Smelting and Refining Company), the Peck Concentrating Plant (the property of the Helena and Livingston Smelting and Reduction Company), and the Helena Electric Lighting and Street Railway Company (now the property of the Helena Light and Traction Company).

The market for power at Helena and vicinity not being sufficient, it was decided in 1900 to enlarge the plant, and construct transmission lines to the City of Butte. To accomplish this result, the company was reorganized as the Missouri River Power Company, a New Jersey corporation, with the writer as Chief Engineer and General Manager. In connection with the enlargement of the plant, it was considered advisable to reconstruct and rearrange the entire plant, both in its hydraulic and electrical elements. In this paper a brief description of the various details of the reconstructed plant has been attempted; and it is thought that some interest may attach to certain of the hydraulic arrangements, and perhaps more especially to the electrical details of the 50 000-volt transmission system to Butte. It should be remembered that this plant was not designed originally for its present service, and that in its reconstruction many arrangements were necessary that would have been changed materially had an entirely new plant been built.

THE GENERATING PLANT.

The generating plant is located at the mouth of the Black Rock Cañon of the Missouri River, near the Canyon Ferry post-office, which is 17 miles from Helena and 65 miles from Butte. The works consist of an earth dam, with a masonry core-wall, located on the east side

PLATE IV.
PAPERS, AM. SOC. C. E.
JANUARY, 1903.
GERRY ON POWER TRANSMISSION.

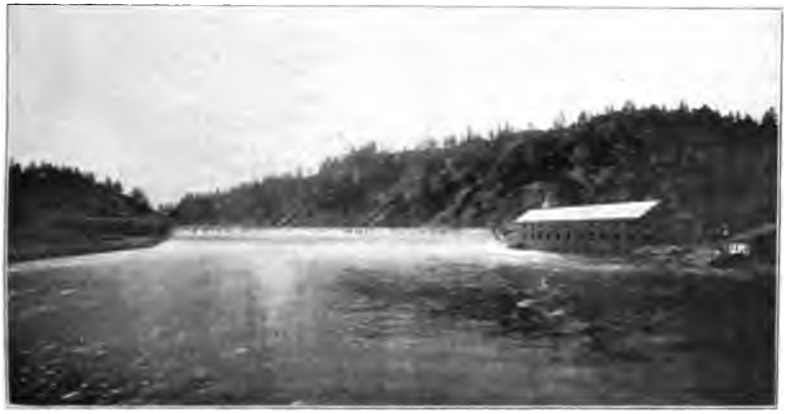


FIG. 1.—CANYON FERRY DAM AND POWER-HOUSE, LOOKING UP-STREAM.

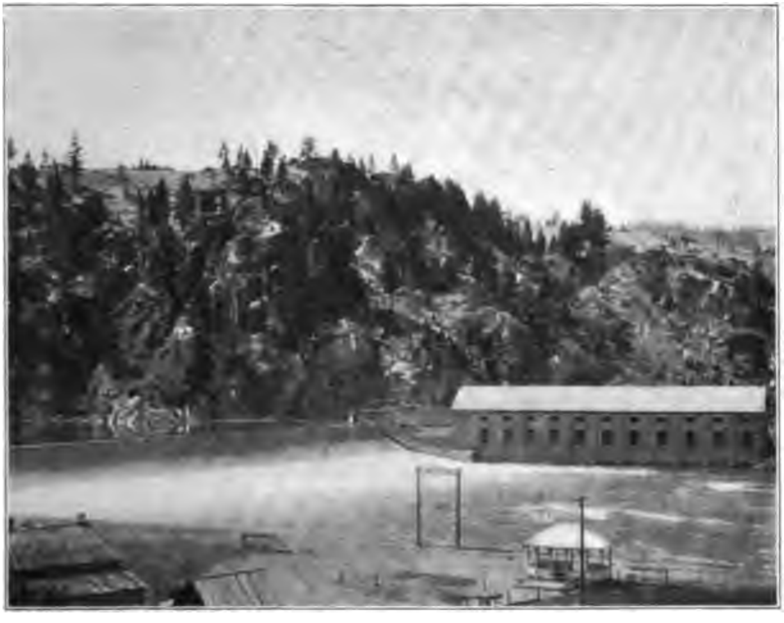


FIG. 2.—CANYON FERRY DAM AND POWER-HOUSE.

DETAILS OF GRID-BARS, GATES, SEALS, ETC.

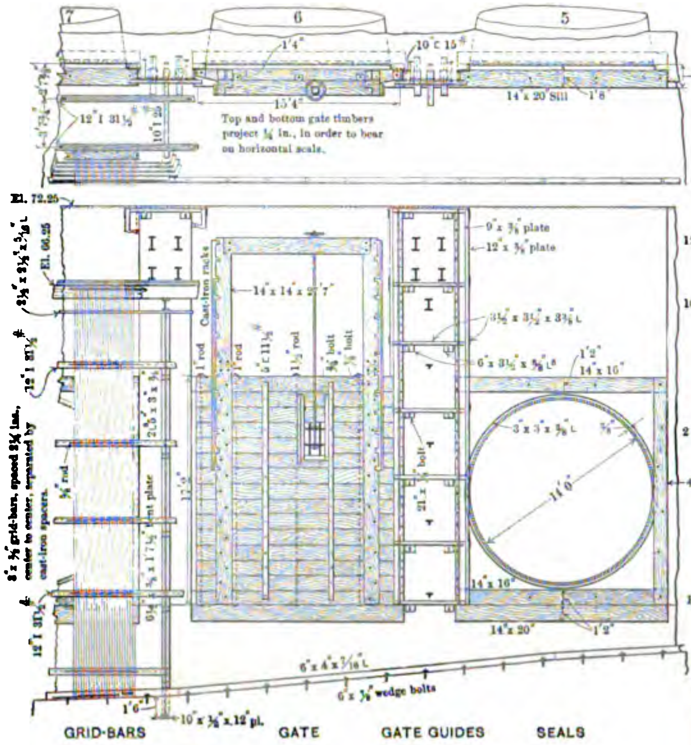
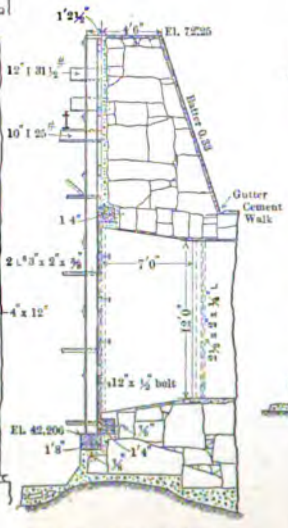
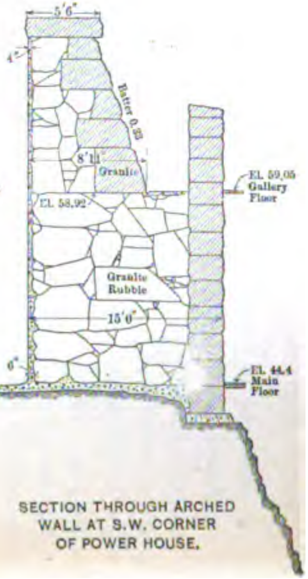


Fig. 4.



SECTION THROUGH CENTER OF PENSTOCK 5

Fig. 5.



SECTION THROUGH ARCHED WALL AT S.W. CORNER OF POWER HOUSE.

Fig. 6.

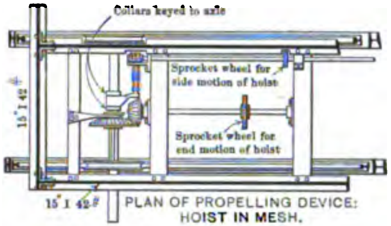
of the river, a timber-crib dam, with masonry abutments, a masonry bulkhead having canal gates, a masonry canal, and a stone power-house. From the east bank to the abutment the distance is approximately 325 ft.; between the abutments is a clear spillway of 472 ft. 9 ins., and fish-stairs 12 ft. in width; and from the west abutment the masonry bulkhead extends 90 ft. to a nearly vertical granite cliff. The total distance from bank to bank on the line of the dam is approximately 900 ft.

Fig. 1 is a general plan of the works; Plate III is a general view of the dam, power-house and canal; Fig. 2 is a section of the timber-crib dam, in its present condition, midway between abutments. The foundations of the power-house, canal walls and west abutment are on granite bed-rock, but in the middle of the stream the bed-rock is found only at exceedingly great depth, the cañon being in the nature of a fissure, or crack, in which the river has deposited silt and gravel. That part of the dam between abutments is a timber crib, rock-filled, and the drawing shows clearly its design, both before and after reconstruction. The dam forms a lake, or reservoir, 7 miles in length and more than 6 sq. miles in area. Fig. 1, Plate IV, is a general view of the dam and power-house, looking up stream from the wagon bridge, which is about 800 ft. below. Fig. 2, Plate IV, is a view from the east side of the river, and shows the power-house and the walls of the cañon.

The four pair of water-wheels received their water originally through two penstocks, but these were removed and a massive stone forebay, or canal, constructed. The dimensions of this canal are given in plan, in Fig. 1. Fig. 1, Plate V, is a general view of this canal, showing the water-wheel head-gates and the west side of the power-house. Fig. 2, Plate V, shows the canal, racks, gates and gate-lifting car. Fig. 3 is a sectional drawing through the canal and power-house, and Plate VI is a plan of the power-house and transformer-room. Figs. 5 and 6 are typical sections through the wall of the canal. The entire canal is of heavy, granite-rubble masonry, with the exception of a few courses on the outside of the wall, as shown. The canal is lined throughout, including the bottom, with Portland cement concrete.

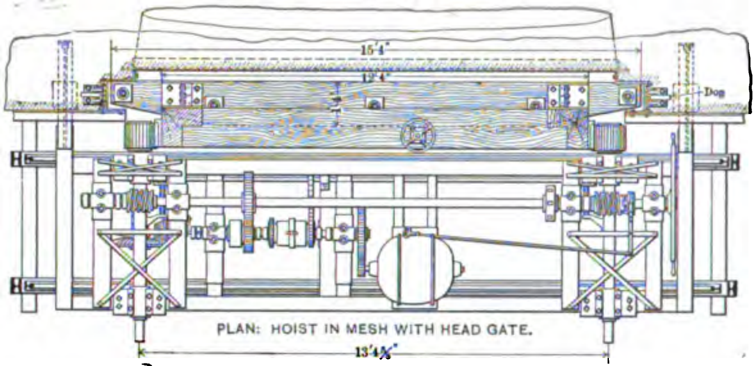
The wheel-cases are of $\frac{5}{16}$-in. steel, 12 ft. in diameter, having conical bell-openings 14 ft. in diameter. These cases are set in the masonry, imbedded in concrete.

ELECTRIC GATE-HOIST.


Collars keyed to axle
Sprocket wheel for side motion of hoist
Sprocket wheel for end motion of hoist
15" I 42#
15" I 42#

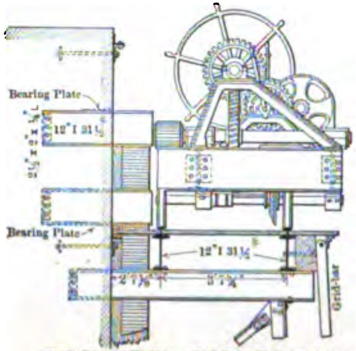
PLAN OF PROPELLING DEVICE: HOIST IN MESH.

Fig. 7



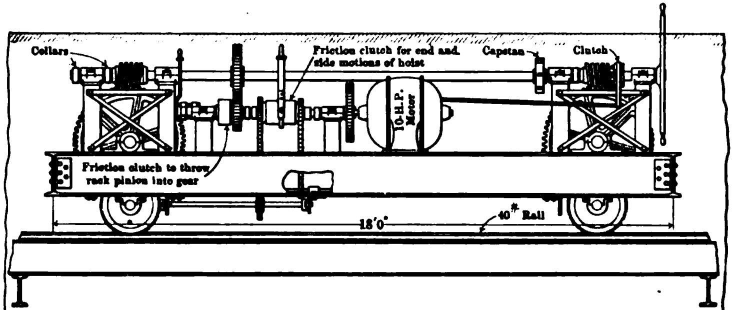
PLAN: HOIST IN MESH WITH HEAD GATE.

Fig. 8



END ELEVATION: HOIST OUT OF MESH.

Fig. 9


Collars
Friction clutch for end and side motions of hoist
Capstan
Clutch
10-H.P. Motor
Friction clutch to throw rack pinion into gear
18'0"
40# Rail

FRONT ELEVATION.

Fig. 10

The main gates are ten in number, 15 ft. 4 ins. in width and 17 ft. 10 ins. in height, of Oregon fir, 16 ins. thick in the center. The gates slide in structural-steel guides built in the masonry.

The grid-bars are 3 x ⅜-in. steel, spaced 2¼ ins. from center to center. They are supported by a structural-steel frame, which also carries the rails for the gate-operating car. The construction of the gates, guides, seals and grid-bars is shown clearly in Fig. 2, Plate V, and Figs. 3, 4, 5 and 6. The arrangement for operating the gates is shown in Figs. 7, 8, 9 and 10. This device consists essentially of a car, with the necessary mechanism, traveling on rails parallel to the east wall of the canal, in front of the gates. The rails on which the car travels support it only when moving between gates, or when moving its pinions into or out of mesh with the racks on the gate-lifting bars. The car receives its power, for all its movements and for operating the gates, from a 10-H.-P. direct-current motor, supplied with current from a trolley. The various motions of the car, and the lifting mechanism, are controlled by clutches operated by levers from a centrally located platform on the car. When the pinions are in mesh and the gates are being operated, the entire thrust is carried directly to the masonry, through 12-in. I-beams set in the wall, as shown in Figs. 8 and 9. The various details of the construction are shown clearly in the drawings referred to.

The power-house building is of granite masonry, 228 ft. 3 ins. in length and 50 ft. in width. A gallery, 18 ft. in width, extends the entire length of the building on the west side; and, at the same floor elevation as the gallery, located between the main power-house and the east wall of the canal, is a transformer-room 154 ft. in length. The general construction of the power-house is shown in Fig. 3 and in Plate VI. The building is entirely of masonry and steel, with the exception of the roof and main floor. The roof-trusses are of steel, and the roof is covered on the outside with corrugated iron. The gallery floor is of steel and concrete construction, and the walls of the house are in the natural stone. All the masonry, including the power-house, canal walls, abutments, and core-walls, is of gray granite, quarried and cut on the premises. Portland cement, of both American and European brands, was used throughout.

There are ten pair of water-wheels driving the main generators, two single wheels and one pair of smaller wheels driving the exciters.

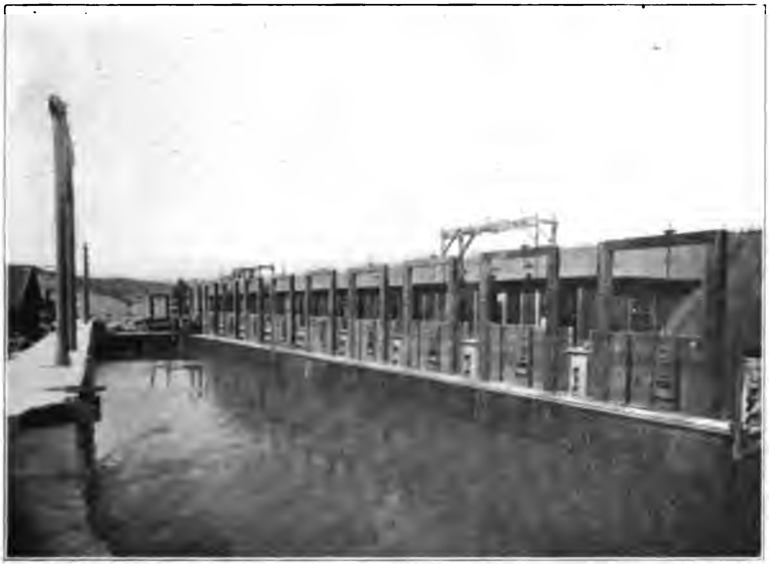


FIG. 1.—CANAL HEAD GATES AND WEST SIDE OF CANYON FERRY POWER-HOUSE.

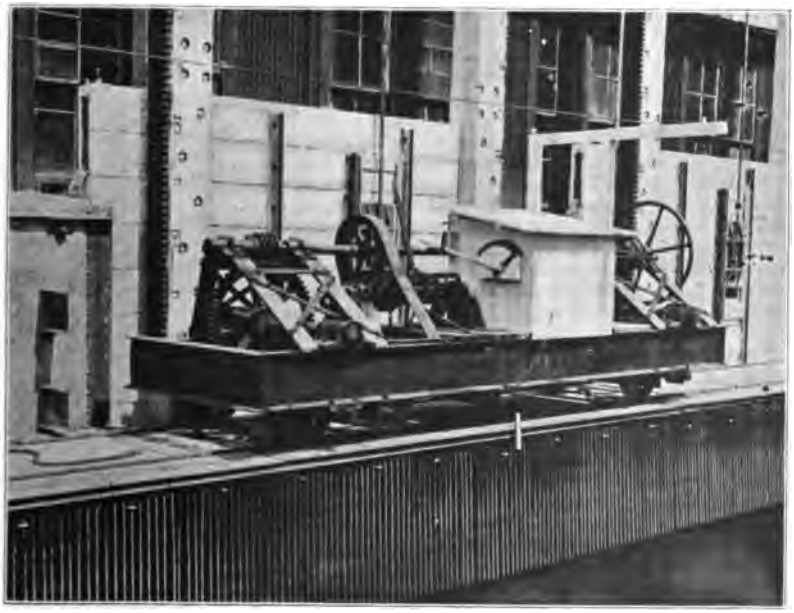


FIG. 2.—GATE-LIFTING CAR.

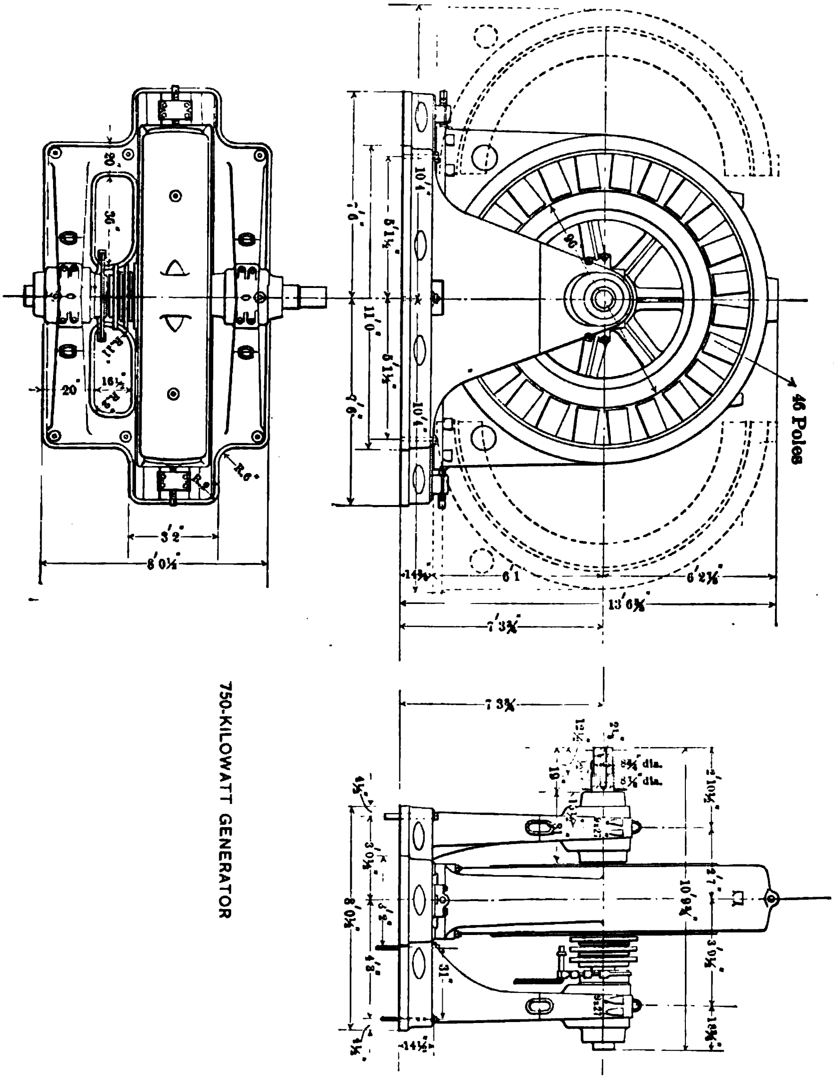


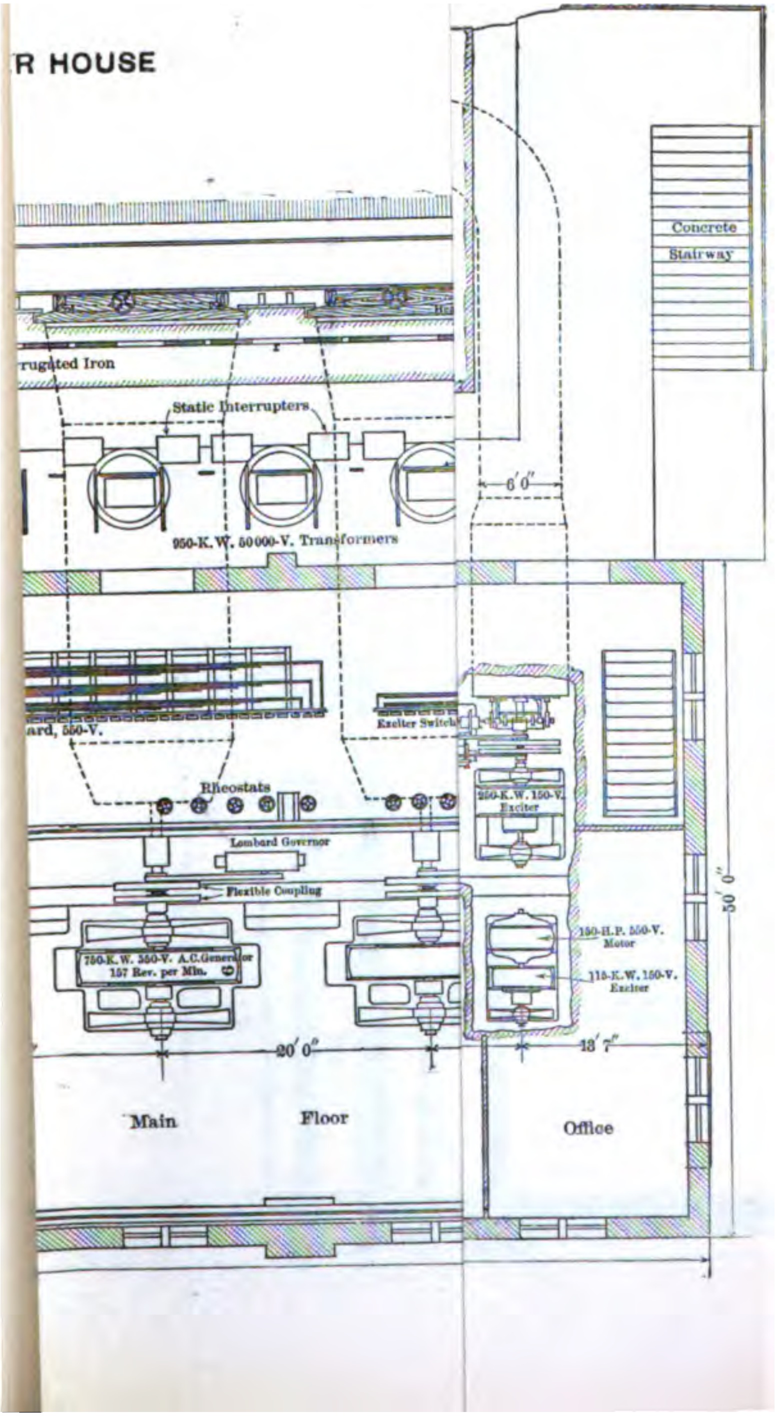
FIG. 11.

750-KILOWATT GENERATOR

The wheels in the old plant are of the "New American" type, and all the new wheels are of the "McCormick" type, manufactured by the S. Morgan Smith Company. Plate VII shows a section through one of the new wheel settings. These wheels have 45-in. runners, and cylinder gates operated by draw-rods through the front head. Outside of the case, attached to the draw-rods, are racks which mesh with the gears operated by the governors. The wheels first discharge the water into central cast-iron draft-chests, then through elliptical draft-tubes into the tail-race. There are two water-bearings on each shaft, one at the outside of the wheel nearest the canal, and the other inside the draft-chest. A third bearing, of a ring-oiling type, is located entirely outside the wheel case and next to the generator coupling. This bearing is also designed to take the thrust in a direction parallel to the shaft, and for that purpose has on the shaft two solid projecting rings, which fit into grooves in the surface of the bearing. Fig. 1, Plate VIII, shows the front head of No. 10 water-wheel, together with the governor and the generator. It also shows two of the exciters, one coupled to a pair of 24-in. McCormick water-wheels, and the other to an induction motor.

The governors in operation are of the "Lombard" type, and this apparatus is too well known to require description other than that the connections between the governors and the water-wheel gate mechanism are made through cut bevel and spur gearing.

The generators have revolving armatures, and are designed to deliver alternating current at three-phase, 60 cycles and 550 volts. The speed is 157 revolutions per minute. Each machine has a rated capacity, in electrical output, of 750 kilowatts at 80% power-factor. The four generators installed originally were two-phase, but they have been rebuilt and converted into three-phase machines. Fig. 11 is a general drawing of one of the new machines. The generators are excited separately by four 150-volt exciters, three of which are driven directly by water-wheels, and one by an induction motor, as previously stated. The connections between the generators and exciters and their water-wheels are made by means of flexible couplings, consisting of cast-iron discs united through rawhide drag-links. The generators and exciters are all of standard types, manufactured by the Westinghouse Electric and Manufacturing Company. A general view of the interior of the station is shown in Fig. 2, Plate VIII, which also gives a good


R HOUSE
Concrete
Stairway
rugated Iron
Static Interrupters
6′ 0″
950-K.W. 50000-V. Transformers
ard, 550-V.
Exciter Switch
Rheostats
250-K.W. 150-V.
Exciter
Lombard Governor
Flexible Coupling
150-H.P. 550-V.
Motor
115-K.W. 150-V.
Exciter
750-K.W. 550-V. A.C.Generator
157 Rev. per Min.
50′ 0″
20′ 0″
13′ 7″
Main
Floor
Office

idea of the mechanical design of the generators and the arrangements in the station.

The switchboards, of blue Vermont marble, are located on the gallery floor in the center of the station. There are seventeen panels in the main board, four in the exciter-board, and four in the 12 000-volt plug-board. Fig. 12 is a general drawing of the main switchboard, and Fig. 1, Plate IX, is a general view of the same board, as installed. The main board consists of ten generator panels, four feeder panels for the 12 000-volt service, two feeder panels for the 50 000-volt service, and one main junction panel in the middle of the board. There are three sets of main bus-bars, extending the entire length of the board, capable of being separated electrically in the middle by means of switches on the junction panel. In the arrangement of the board, starting at one end, are five generator panels, two feeder panels for the 12 000-volt service, one feeder panel for the 50 000-volt service, and the junction panel. On the other side of the junction panel the same number of feeder and generator panels is arranged in reverse order, so that all the feeder panels are grouped together in the center of the board, with the generator panels at the ends. By opening the switches on the junction panel, the board is divided electrically into two independent sections, either of which may be shut down for repairs while the other is in service. Each generator panel is provided with circuit-breakers, a polyphase wattmeter, an ammeter, and three sets of lever switches. Each feeder panel is provided with circuit-breakers, three ammeters, and three sets of lever switches. The junction panel has three sets of lever switches, and six polyphase wattmeters, one for each main circuit. The generator field switches and the integrating wattmeters for the feeders are mounted on small marble slabs, secured to the girder supporting the traveling crane, and are directly in front of the main board. The rheostats are mounted under the gallery floor, and are controlled by hand-wheels on pedestals, which are in front of their respective generator panels. Fig. 13 is a drawing of the exciter board, which is of the same general appearance as the main board. It has two separate sets of bus-bars, and each panel has circuit-breakers, a voltmeter, an ammeter, and two sets of lever switches.

There are twelve transformers, of 330 kilowatts each, for the 12 000-volt service. These transformers are oil-insulated, air-cooled, and are

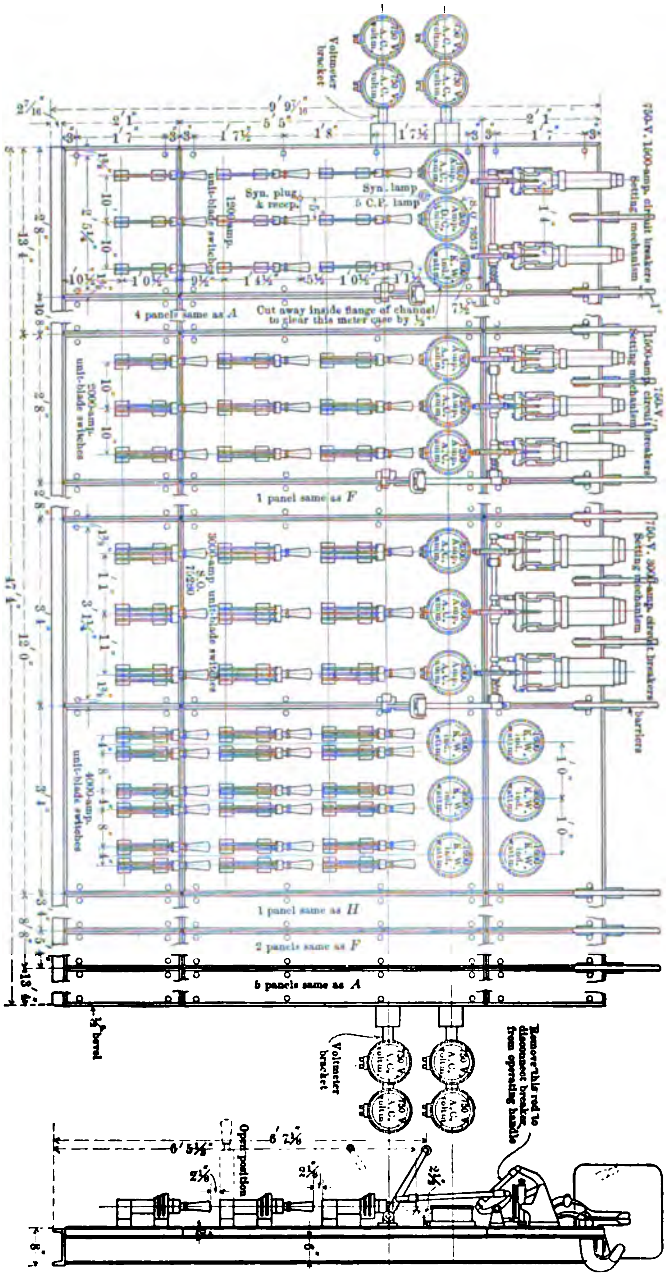

A
B C D E
F
G
H
I
J
K L
M N O P Q
Voltmeter bracket
750-V. 1500-amp. circuit breakers Setting mechanism
Syn. plug & recep.
Syn. lamp 5 C.P. lamp
1200-amp. unit-blade switches
4 panels same as A
Cut away inside flange of channel to clear this meter case by ½"
2000-amp. unit-blade switches
750-V. 1500-amp. circuit breakers Setting mechanism
1 panel same as F
3000-amp. unit-blade switches
750-V. 3000-amp. circuit breakers Setting mechanism
barriers
4000-amp. unit-blade switches
1 panel same as H
2 panels same as F
5 panels same as A
Removable rod to disconnect breaker from operating handle
Open position
½" bevel
9' 9⁵⁄₁₆"
47' 4"
13' 4"
12' 0"
6' 7¼"
6' 5½"

FIG. 12.

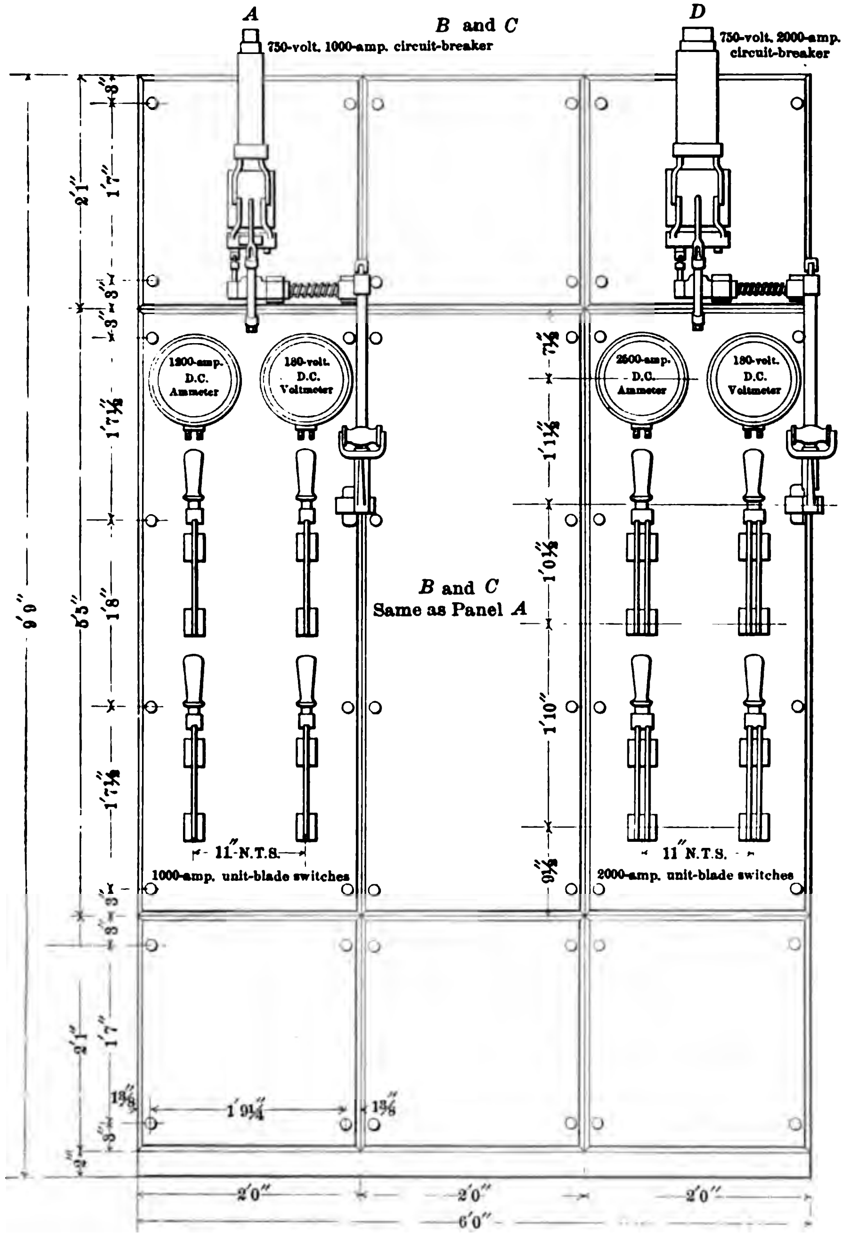

A
B and C
750-volt, 1000-amp. circuit-breaker
D
750-volt, 2000-amp. circuit-breaker
1200-amp. D.C. Ammeter
180-volt. D.C. Voltmeter
2500-amp. D.C. Ammeter
180-volt. D.C. Voltmeter
B and C
Same as Panel A
11" N.T.S.
1000-amp. unit-blade switches
11" N.T.S.
2000-amp. unit-blade switches
9' 0"
2' 1"
5' 5"
2' 1"
3"
1' 7"
3"
3"
3"
1' 7½"
1' 8"
1' 7½"
3"
3"
3"
1' 7"
3"
2"
7½"
1' 1⅛"
1' 0⅛"
1' 10"
9⅛"
1⅜"
1' 9¼"
1⅜"
2' 0"
2' 0"
2' 0"
6' 0"

FIG. 13.

arranged in four groups for three-phase delta connection. They are placed on the gallery floor, six transformers at each end of the switchboard. For the 50 000-volt service, there are six transformers of 950 kilowatts each. These transformers are oil-insulated, water-cooled, are arranged in two groups for delta connection, and are placed in the transformer-room between the wall of the power-house and the east wall of the canal. The 50 000-volt transformers are in heavy, boiler-iron tanks filled with a petroleum oil, and are cooled by means of brass pipes, immersed in the oil, through which circulates water from the canal. As the cooling coils are at an elevation which at times is above the water in the canal, the piping is arranged, by means of by-pass valves, so that the system can be filled and the water siphoned through the coils, discharging through draft-tubes extending below the level of the tail-race. A good head is secured by this arrangement, and the circulation of the cooling water is excellent. Gauges for measuring the flow of the cooling water, and thermometers for measuring the temperature of the oil and water, are on the transformers. Fig. 1, Plate X, is an end view of the 50 000-volt transformer-room, showing the transformers in position.

For the protection of the 12 000-volt service from lightning, standard type, "R," Wurts, lightning arresters are used. These consist of choke-coils and gaps, arranged so as to afford a multiple path to ground. As this apparatus is very well known, no detailed description need be given. For the protection of the 50 000-volt service from lightning, new apparatus has been designed. This consists essentially of two parts, the static interrupters and the lightning arresters proper. The static interrupters, so-called, consist of choke-coils and electrical condensers of small capacity. These coils and the condensers, immersed in a tank containing oil, constitute the static interrupters. Each lightning arrester contains 114 units of six gaps, about $\frac{1}{32}$ in. in width, and one large adjustable gap next to the line. The units are mounted on the face of marble panels, and around part of the units is shunted a resistance; and, in series with all the gaps, between line and ground, is a resistance. The connections of the static interrupters and lightning arresters are given diagramatically in Fig. 14. It will be seen that the choke-coils of the interrupter are connected in series with the transformer windings to be protected, and that the condenser is connected between the transformer terminal and the ground. The

PLATE VII.
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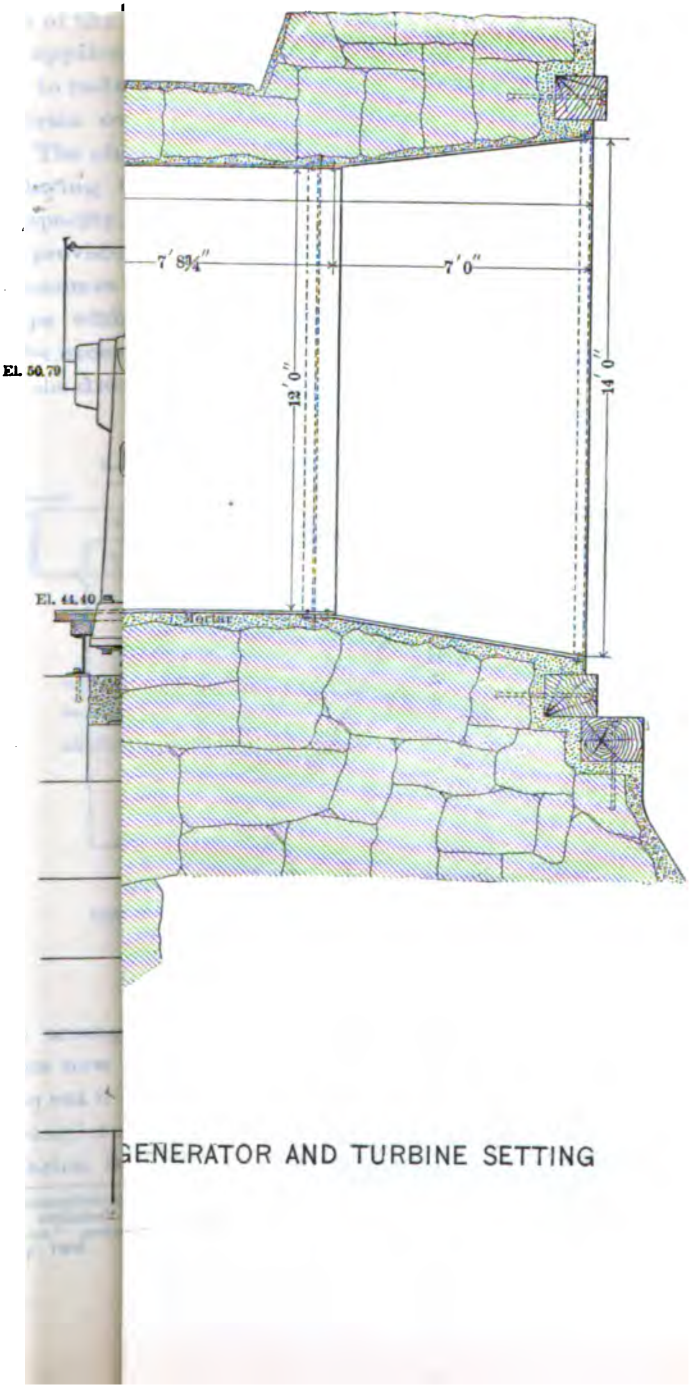
GERRY ON POWER TRANSMISSION.



GENERATOR AND TURBINE SETTING

to their respective panels on the switchboard. At the switchboard two of the legs of each generator circuit pass through circuit-breakers, and all three of the legs are connected with three sets of single-pole knife-switches. Each set of knife-switches, upon being closed, connects the three legs of each generator circuit with a set of bus-bars at the back of the switchboard. There are three sets of such bus-bars, and any generator may be connected with any one or all. After passing to the bus-bars the current is first conducted through the switches and the circuit-breakers on the feeder panels, then to the transformers. Especial attention is directed to the arrangement of the switches, circuit-breakers, and instruments, in this part of the wiring.

The current from the 12 000-volt transformers passes to the four-circuit plug-board, which is arranged so that any one of the four circuits may be connected with any one set of transformers, or any number of sets of transformers may be joined to any of the lines, either singly or in multiple. After leaving the plug-board the 12 000-volt current passes through lightning arresters and then to the circuits extending to Helena and adjacent points.

From the six 50 000-volt transformers the current passes through static interrupters and high-tension switches, and is then united by a delta connection, after which it passes through a set of high-tension line-switches to the circuits extending to Butte. The lightning arresters, proper, are connected with each leg of these circuits just before leaving the building. Between the two 50 000-volt circuits are high-tension switches, arranged so that both sets of transformers may be operated together, either on one or both lines; or both lines may be operated from one set of transformers. The arrangement of switches, also, is such that any transformer may be put into or out of service at any time, without interfering with the operation of the plant. All the 50 000-volt main wiring is of 1 000 000 or 800 000-circular mil cable, insulated with rubber, and protected with a lead sheath. The 12 000-volt wiring is No. 4, solid copper, insulated with $\frac{5}{16}$-in. pure para rubber, covered with double cotton braiding, and is supported on porcelain line-insulators. The 50 000-volt wiring is of No. 4 copper, having an insulation of $\frac{7}{16}$-in. pure para rubber, protected with double cotton braiding, and is supported on the regular, glass, line-insulators and pins.

PLATE VIII.
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GERRY ON POWER TRANSMISSION.

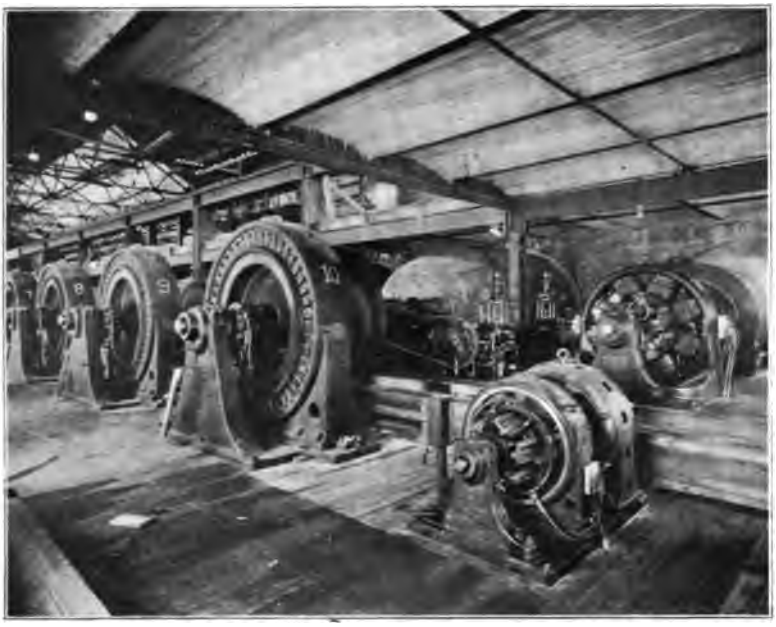

FIG. 1.—GENERATOR, WHEEL-CASE AND GOVERNOR.

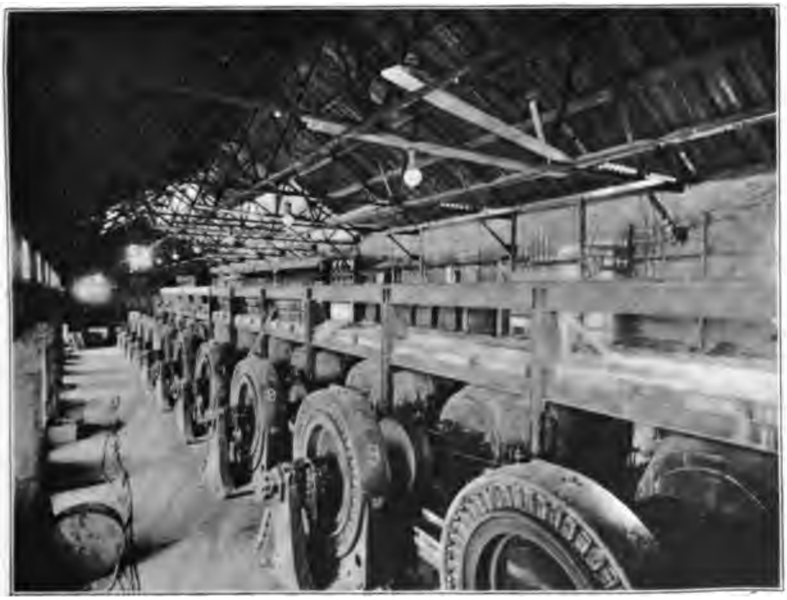

FIG. 2.—INTERIOR OF CANYON FERRY POWER-HOUSE.

oU

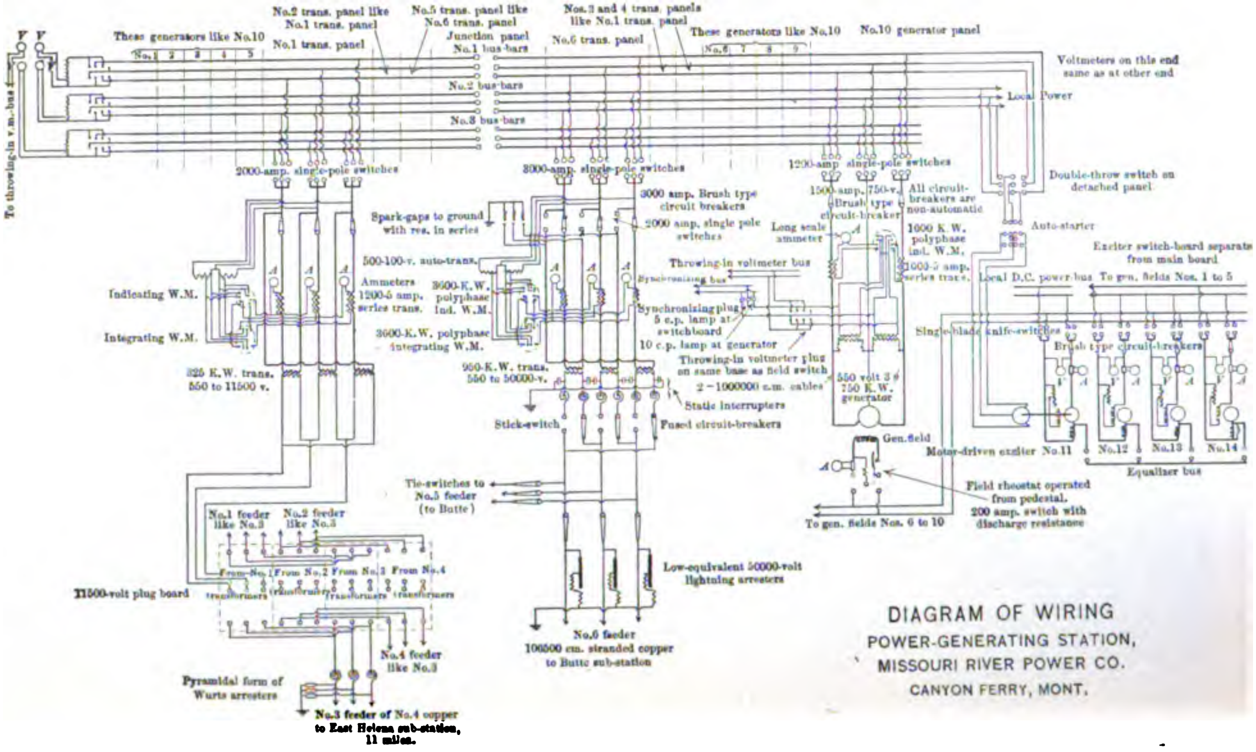
To throwing-in v.m.-bus
V
V
These generators like No.10
No.1 2 3 4 5
No.2 trans. panel like No.1 trans. panel
No.1 trans. panel
No.5 trans. panel like No.6 trans. panel
Junction panel
No.1 bus-bars
No.2 bus-bars
No.3 bus-bars
Nos.3 and 4 trans. panels like No.1 trans. panel
No.6 trans. panel
These generators like No.10
No.6 7 8 9
No.10 generator panel
Voltmeters on this end same as at other end
Local Power
2000-amp. single-pole switches
3000-amp. single-pole switches
1200-amp single-pole switches
Double-throw switch on detached panel
Spark-gaps to ground with res. in series
3000 amp. Brush type circuit breakers
2000 amp. single pole switches
1500-amp. 750-v. Brush type circuit-breaker
All circuit-breakers are non-automatic
Long scale ammeter
1000 K.W. polyphase ind. W.M.
1000-5 amp. series trans.
Auto-starter
Exciter switch-board separate from main board
Local D.C. power-bus
To gen. fields Nos. 1 to 5
500-100-v. auto-trans.
Throwing-in voltmeter bus
Synchronizing bus
A
Indicating W.M.
Ammeters 1200-5 amp. series trans.
3600-K.W. polyphase ind. W.M.
Synchronizing plug
5 c.p. lamp at switchboard
10 c.p. lamp at generator
Throwing-in voltmeter plug on same base as field switch
2 – 1000000 c.m. cables
Integrating W.M.
3600-K.W. polyphase integrating W.M.
Single-blade knife-switches
Brush type circuit-breakers
V
325 K.W. trans. 550 to 11500 v.
950-K.W. trans. 550 to 50000-v.
550 volt 3 φ 750 K.W. generator
Static interrupters
Stick-switch
Fused circuit-breakers
Gen. field
Motor-driven exciter No.11
No.12
No.13
No.14
Equalizer bus
Field rheostat operated from pedestal.
200 amp. switch with discharge resistance
To gen. fields Nos. 6 to 10
Tie-switches to No.5 feeder (to Butte)
No.1 feeder like No.3
No.2 feeder like No.3
From No.1 transformers
From No.2 transformers
From No.3 transformers
From No.4 transformers
11500-volt plug board
Low-equivalent 50000-volt lightning arresters
No.4 feeder like No.3
No.6 feeder 100500 cm. stranded copper to Butte sub-station
Pyramidal form of Wurts arresters
No.3 feeder of No.4 copper to East Helena sub-station, 11 miles.

DIAGRAM OF WIRING
POWER-GENERATING STATION,
MISSOURI RIVER POWER CO.
CANYON FERRY, MONT.

FIG. 15.

THE TRANSMISSION LINES.

There are three main pole-lines from the generating station: One carrying four power-circuits, each consisting of three No. 4, solid copper wires, and also a telephone circuit of two No. 10, copper wires. This line extends to the East Helena sub-station, where all the circuits pass through a four-panel plug-board, and lightning arresters of construction and arrangement similar to those on the same circuits at Canyon Ferry. Three circuits leave this sub-station, and, by means of the plug-board, any one or more of the four incoming circuits may be connected either with the sub-station lowering transformers, or with the three outgoing circuits, in any desired combination. After leaving the sub-station, the three circuits continue for about a mile on the same pole-line, and then branch—one circuit extending a distance of 5 miles to the Big Indian Mine, and the other extending 5 miles to the sub-station in Helena. The general design of the pole top, as arranged for the four 12 000-volt circuits leaving the generating station, is shown in Fig. 16.

The poles on the 12 000-volt lines are of Idaho cedar, the cross-arms of Oregon fir, the braces of angle iron, and the insulators of porcelain. The poles have from 9 to 12-in. tops, vary in length from 35 to 60 ft., when necessary to maintain the desired grade, are spaced at an average distance of 110 ft., and are set from 6 to 8 ft. in the ground. The main wires are not transposed, but the telephone wires are reversed in position at every third pole. The construction is heavy and rigid throughout, and has proved very satisfactory, as shown by the four years of unbroken service, almost without any expense for repairs.

The high voltage used on the Butte lines made necessary a special and somewhat novel construction. Each of the two pole-lines, from the Canyon Ferry generating plant to the Butte sub-station, carries three bare copper cables, arranged in a triangular position, 78 ins. apart. Each cable has an area of 106 000 circular mils, and is composed of seven strands. Fig. 17 shows the pole top, and Fig. 18 the insulator, sleeve and pin. Fig. 2, Plate IX, is a view of the pole-line taken about one mile from Canyon Ferry, and Fig. 2, Plate X, shows a 50 000-volt insulator and sleeve assembled on a pin.

The poles on the 50 000-volt lines are of Idaho cedar, the cross-arms of Oregon fir, the braces and pins of white oak, and the insu-

PLATE IX.
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GERRY ON POWER TRANSMISSION.

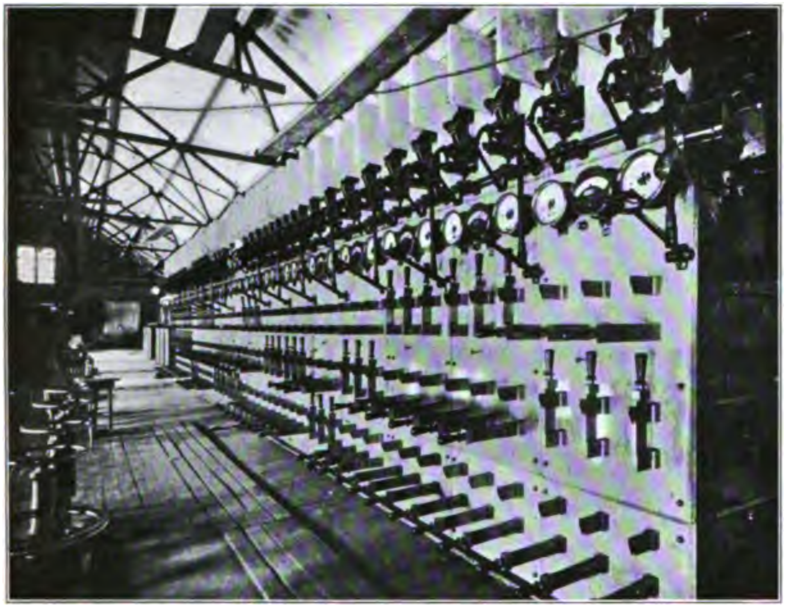


FIG. 1.—MAIN SWITCHBOARD, CANYON FERRY POWER-HOUSE.

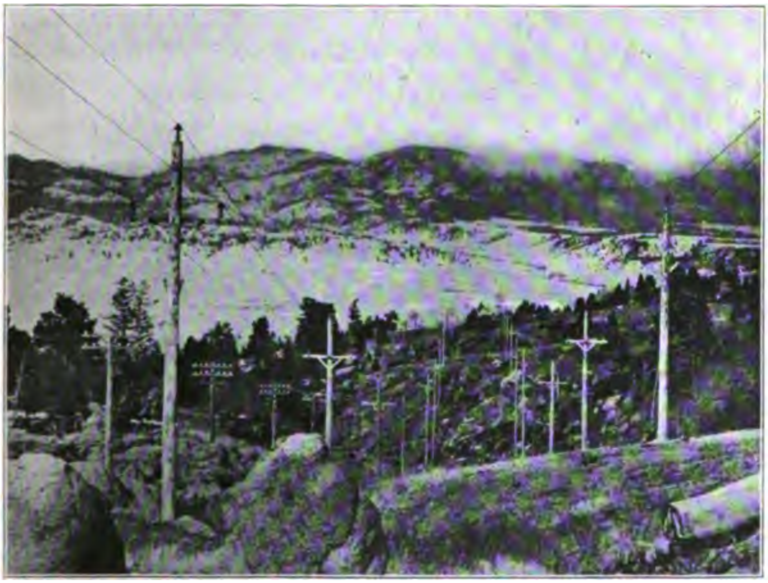
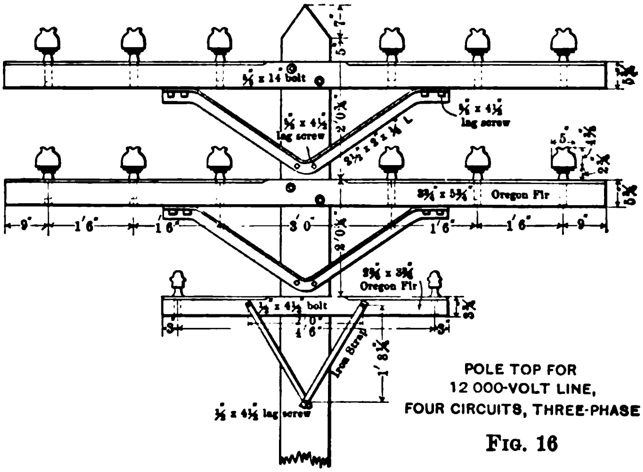
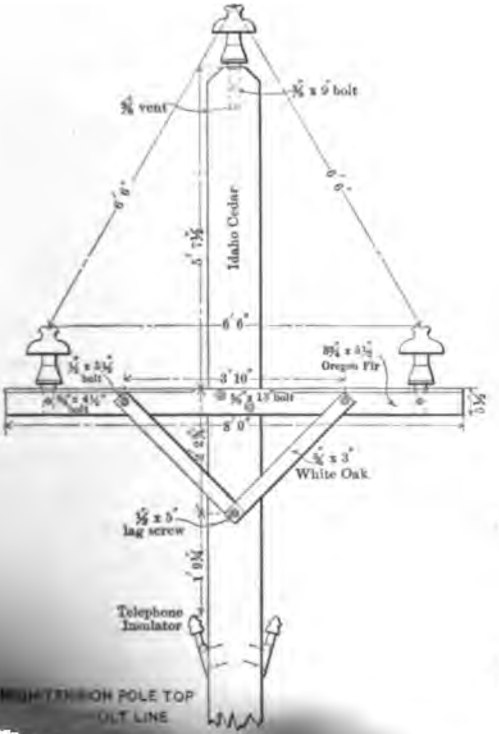


FIG. 2.—POLE-LINES NEAR CANYON FERRY.

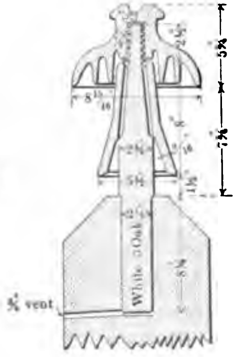


POLE TOP FOR
12 000-VOLT LINE,
FOUR CIRCUITS, THREE-PHASE

FIG. 16



HIGH-TENSION POLE TOP
[illegible] OLT LINE

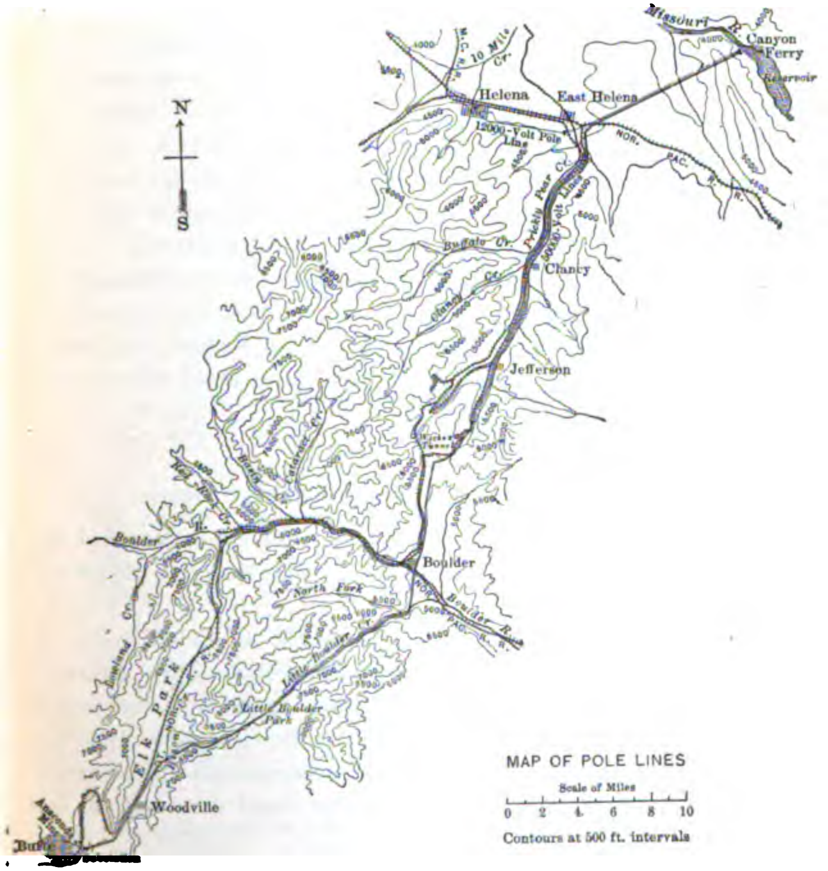


SECTION OF
50 000-VOLT
HIGH-TENSION INSULATOR,
SLEEVE, PIN, AND POLE TOP.

FIG. 18

lators and sleeves of glass. The cross-arms, braces and pins are bolted together, the construction being very rigid. The pins in the top of the poles are of larger size and of greater length than those in the cross-arms, on account of the greater strains there present. The pins were prepared especially by being first dried and then boiled in paraffin until every vestige of moisture was removed. Wood prepared in this way will stand very great electrical strains, and the pins were tested frequently to 60 000 volts, without sign of failing.

The insulation of the circuits depends on the insulators, sleeves and pins, combined; the cross-arms and poles are not considered to have any part. The glass sleeves are not connected in any way with the insulators, and merely rest on a shoulder of the pins, as shown in Fig. 18. The object of the sleeves is to prevent the surface of the pins from becoming wet in a driving rain, thus carrying the ground potential above the level of the cross-arms. This function they perform admirably, but if the pins were not especially treated, so as to possess high insulating qualities, the sleeves would be useless. With metal pins, or even ordinary wooden pins, which for such high potentials are practically conductors, the absolute insulation, the air path to ground, and the electro-static capacity, are affected to such an extent that the efficiency of the combination, as a line-insulating device, is reduced materially. Each of the main circuits is transposed five times, making two complete turns between the power-station and the Butte sub-station. The telephone circuit, as shown in Fig. 17, is on one pole-line, only, and is composed of two No. 10, copper wires on double-petticoat pony-glass insulators. This circuit is transposed every fifteen poles. The switching arrangements at Canyon Ferry and at Butte are such that the power circuits can be operated either singly or in multiple. The two Butte lines are parallel, and are 50 ft. apart, where the nature of the ground will permit. The poles are from 35 to 75 ft. in length, the tops being from 8 to 12 ins. in diameter, and the butts from 12 to 24 ins. in diameter, according to the length. They are set from 6 to 8 ft. in the ground, and the standard spacing is 110 ft., with a maximum spacing of 150 ft., when required by the nature of the ground. The angle turned on any one pole does not exceed 20°, except by special construction. A survey of the entire route was made, including levels at each pole; a ground profile was prepared, and the grade line for the



MAP OF POLE LINES

Scale of Miles

Contours at 500 ft. intervals

Fig. 19.

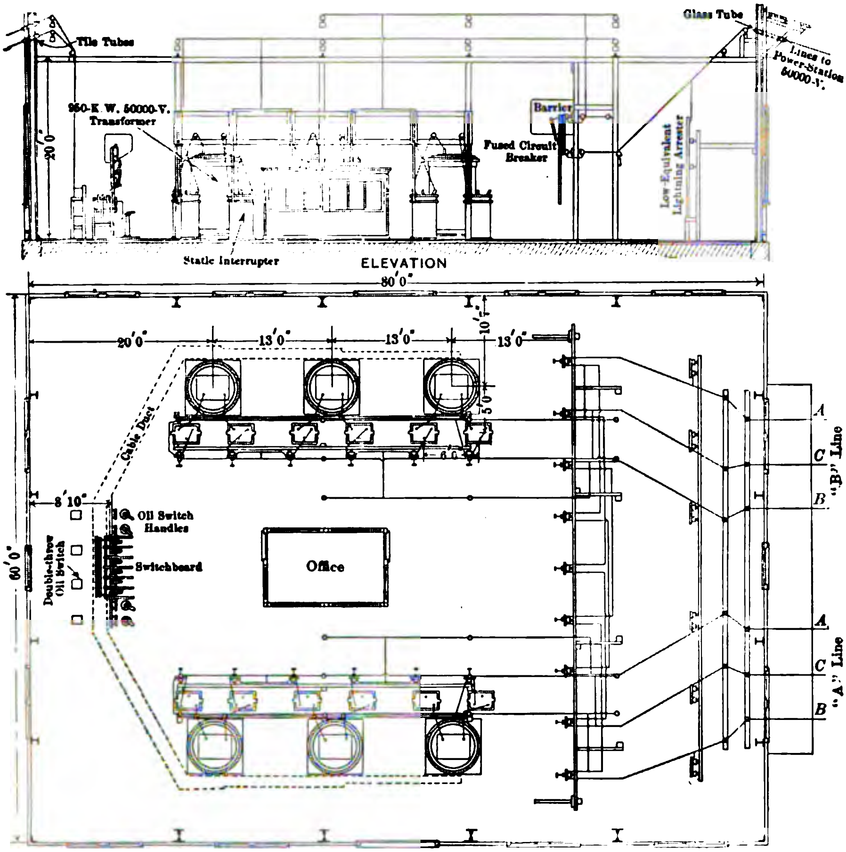
top of the poles drawn in. For the greater part of the distance, a right-of-way, 200 ft. in width, was obtained by purchase or condemnation, but, at a few points, and in passing through towns, it was necessary to follow the public highways, and in some of the narrow cañons, where there were already two railroads, it became necessary to follow in part the railroad rights-of-way. All the timber and brush within 50 ft. of the poles on either side was cut, and all high timber at a greater distance, which in falling could possibly injure the line. The contours on the map, Fig. 19, give an excellent idea of the nature of the country through which the lines are constructed. Starting from Canyon Ferry at an elevation of 3 650 ft. above mean sea level, the Butte lines pass over three distinct summits and reach a maximum elevation of 7 300 ft. Much of the country is very rough and wild, and the section between Boulder and Woodville is practically without inhabitants. Through this section it was necessary to build wagon roads, in order to handle the material, and much of the right-of-way was cleared through heavy timber. In certain sections the grades average 500 ft. to the mile, and the transportation of the material was one of the serious problems.

THE SUB-STATIONS AND SECONDARY DISTRIBUTION.

There are three sub-stations connected with the system, and at a few other points power is delivered directly from the 12 000-volt circuits.

The East Helena sub-station is operated at 12 000 volts. It contains oil-insulated and air-cooled transformers, also lightning arresters and plug-boards similar to those installed at the power-station, and already described. Practically the entire capacity of this sub-station is utilized by the East Helena Smelter for a great variety of purposes, all the power at the works being derived from this source.

The Helena sub-station is also on the 12 000-volt circuits. It contains high-tension apparatus similar to that at East Helena and at the power-station. From this point is supplied all the incandescent and arc lighting, and the street railway and other electrical power for the City of Helena. As the apparatus here installed has already been described, and as this sub-station, as well as that at East Helena,



BUTTE SUB-STATION

FIG. 20.

represents only standard practice, no further detailed description is attempted.

The largest of the sub-stations is at Butte, having a transformer capacity of about 8 000 H.-P. The building is of steel and iron, with a brick floor and concrete foundations. The roof is lined with asbestos paper, held in position by wire netting. Fig. 20 is a plan of the building, showing the location of the principal apparatus. Fig. 1, Plate XI, is an exterior view of the transformer building, showing the method of entering the 50 000-volt lines. Fig. 2, Plate XI, is an interior view, showing the transformers, static interrupters, high-tension switches and wiring. Fig. 21 is a diagram of the wiring and connections of the apparatus. The 50 000-volt wiring is supported on glass line-insulators, and is of No. 4, solid copper, rubber-insulated wire, the same as that used in the generating station. The 2 200-volt secondary wiring from the transformers to the switchboard is of 800 000-circular mil cable, rubber-insulated, lead-covered, and laid in conduits under the floor. The 50 000-volt lightning arresters are duplicates of those in the generating stations, and are connected with each conductor immediately upon entering the building. After passing the lightning arresters, the main circuits pass through high-tension, fused circuit-breakers, then divide into a delta connection, inside of which is a pair of high-tension, fused circuit-breakers for each transformer, and also the static interrupters. Between the high-tension, line circuit-breakers and the branch of the delta connection, there are tapped, from each leg of the circuits, connections, through high-tension circuit-breakers, arranged so that the lines may be connected in multiple. All these connections are shown in the diagram.

There are six lowering transformers, of 950 kilowatts each, which are exact duplicates of those installed in the generating station, except that the coils of the low-tension side are connected in series, so as to give the electrical pressure of 2 200 volts instead of 550 volts. The six transformers are arranged in two groups, and on the 2 200-volt side are placed knife-switches and circuit-breakers, connected in the single-phase circuits inside of the delta connections. The three-phase connections are made at the main transformer panels of the 2 200-volt switchboard. There are two transformer panels, one for each group of transformers, and four main distributing panels. On each transformer panel is mounted a three-pole circuit-breaker, three ammeters,

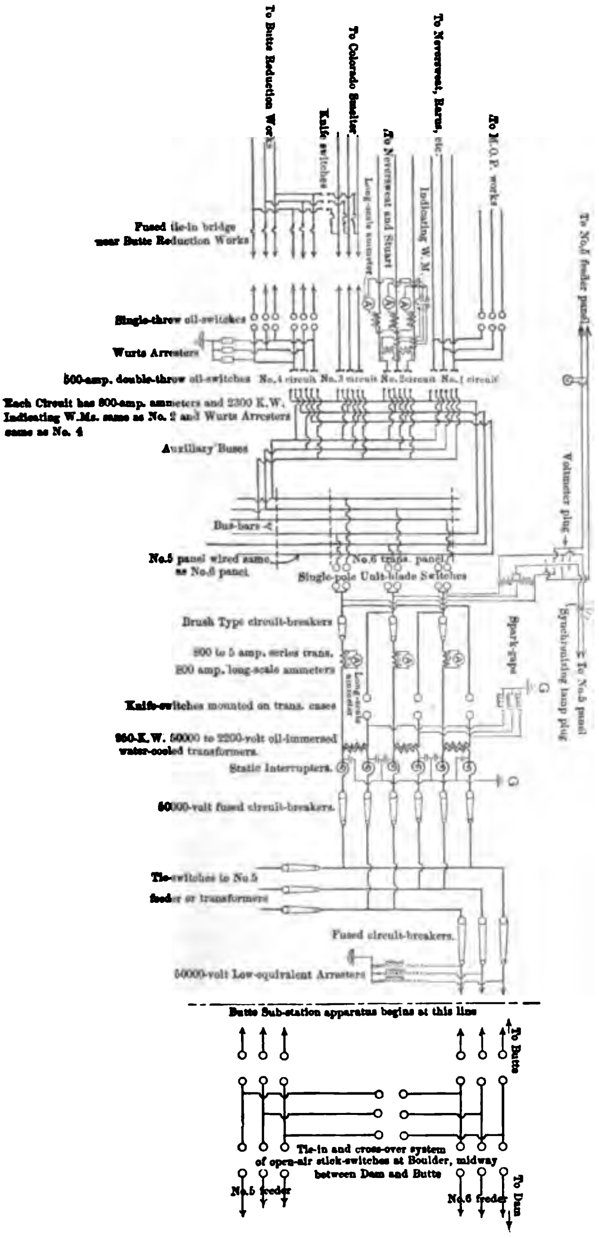
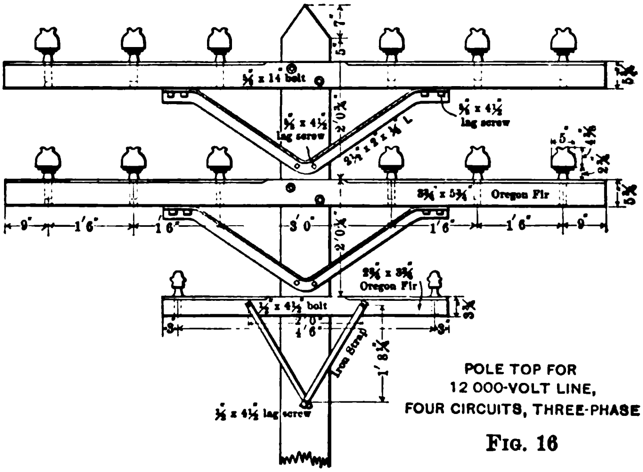

To Butte Reduction Works
To Colorado Smelter
Knife switches
To Neversweat and Stuart
Long-scale ammeter
To Neversweat, Barus, etc.
Indicating W.M.
To M.O.P. works
To No.5 feeder panel
Fused tie-in bridge near Butte Reduction Works
Single-throw oil-switches
Wurts Arresters
500-amp. double-throw oil-switches
No.4 circuit
No.3 circuit
No.2 circuit
No.1 circuit
Each Circuit has 800-amp. ammeters and 2300 K.W. Indicating W.Ms. same as No. 2 and Wurts Arresters same as No. 4
Auxiliary Buses
Bus-bars
No.5 panel wired same as No.6 panel.
No.6 trans. panel
Single-pole Unit-blade Switches
Voltmeter plug
Synchronizing lamp plug
To No.5 panel
Spark-gaps
G
Brush Type circuit-breakers
800 to 5 amp. series trans.
800 amp. long-scale ammeters
Long-scale ammeter
Knife-switches mounted on trans. cases
950-K.W. 50000 to 2200-volt oil-immersed water-cooled transformers.
Static Interrupters.
G
50000-volt fused circuit-breakers.
Tie-switches to No.5 feeder or transformers
Fused circuit-breakers.
50000-volt Low-equivalent Arresters
Butte Sub-station apparatus begins at this line
To Butte
Tie-in and cross-over system of open-air stick-switches at Boulder, midway between Dam and Butte
No.5 feeder
No.6 feeder
To Dam

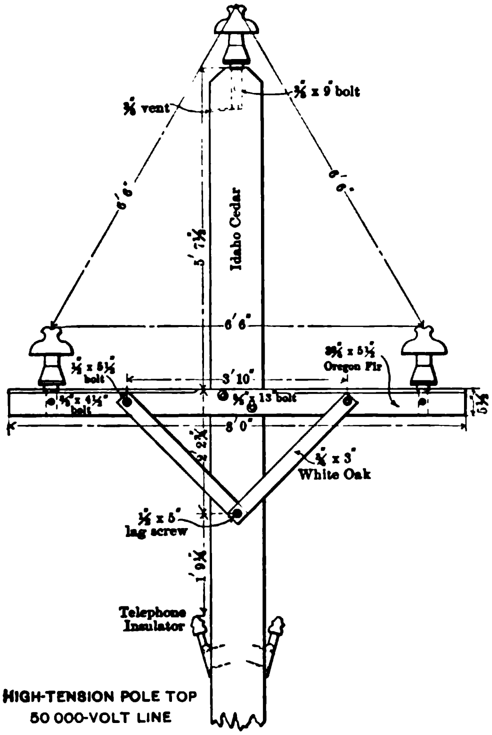
DIAGRAM OF WIRING,
BUTTE SUB STATION
MISSOURI RIVER POWER CO.

FIG. 21.



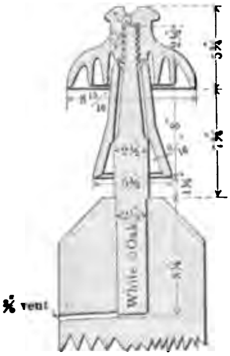
POLE TOP FOR
12 000-VOLT LINE,
FOUR CIRCUITS, THREE-PHASE

FIG. 16



HIGH-TENSION POLE TOP
50 000-VOLT LINE

FIG. 17



SECTION OF
50 000-VOLT
HIGH-TENSION INSULATOR,
SLEEVE, PIN, AND POLE TOP.

FIG. 18

large motors, of 200, 300, 600 and 800-H.-P. sizes, mostly of the induction type. Fig. 1, Plate XII, shows one of three induction motors of 300 H.-P. operating at the Colorado Smelter. Fig. 2, Plate XII, shows an 800-H.-P. induction motor of 175 revolutions per minute, used in driving an air compressor at the Anaconda Mines. This last-mentioned motor is believed to be the largest induction motor of such slow speed ever installed.

THE OPERATION OF THE PLANT.

In the operation of a transmission plant and system like that of the Missouri River Power Company, starting with a given plant and water supply, the desired result is the delivery, at distant points, of the greatest amount of electrical energy, in the most salable and satisfactory form, at the lowest possible cost.

For the generation of the power, a certain river flowage is available, varying with the seasons and the years. There is also available a large pond or reservoir which may be drawn upon to supply water in excess of the river flowage for short periods of time. The first important consideration is the nature of the load, whether variable or steady, and whether extending over a few hours or the entire day. The most convenient way of expressing this condition is by reference to the load factor, *i. e.*, the ratio of the average to the maximum load, expressed as a percentage, for the period of time over which the factor is determined. Integrating wattmeters furnish a ready means for determining with accuracy the average electrical power, and the maximum power can always be measured by various indicating or recording instruments. The load factors of several circuits supplying power for a variety of industrial purposes will usually differ widely, and the best result, as far as station loading is concerned, will be obtained by uniting all on one set of bus-bars, and operating the entire station as a unit. Sometimes this is impossible on account of different electrical pressures being demanded, or on account of certain circuits requiring greater refinement in regulation than others. The conditions at Canyon Ferry have been adjusted so that it is possible to operate all circuits together, so that the generating machinery is working at one load factor, or about 90% for the 24 hours; the load factors of the several circuits varying meanwhile among themselves from 95% on some to 10% on others. It is evident that the higher the load factor, the smaller the machinery capacity required in service to carry a given average load; and it also follows, in general, that the efficiency is greater because the machinery can be operated more nearly at its full load.

The load factor also has an important bearing upon the speed regulation of the water-wheels, and upon the electrical regulation of the system. Commercial considerations frequently require the acceptance from a customer of a power load of load factor, but it is the best practice to regulate the design so that such loads can be combined with others, resulting in an average condition more favorable to economical operation. It is the practice of the Missouri River Power Company to operate the entire station as a unit, connected in multiple, but the design is such that circuits can be operated separately under special conditions, or in emergencies of any kind. The station load factor being determined, the amount of average power which can be generated will depend upon the flow of the river, provided there is a pond or reservoir affording water storage sufficient to permit the carrying of the peak loads, without seriously affecting the head. This is a most important matter, as it permits the plant to carry an average load fully up to the flowage of the river, while, without such a reservoir, the power generated could not exceed the maximum at the station, which would be materially less than the average. At Canyon Ferry the pond is ample for this purpose.

Next in importance to the form and amount of loading on the station is the question of speed regulation. For many years close speed regulation was thought impossible for water-wheels driving machinery subject to suddenly varying loads; but the difficulties have been overcome, and it has been found that very satisfactory results can be obtained by correct designing, and the use of proper governors to actuate the water-wheel gates. The first consideration is to have such hydraulic design that the water can pass freely to the wheels, and to avoid those arrangements which require a considerable change in the velocity of the water, with varying gate on the wheels; such, for example, as long penstocks having little hydraulic grade. If the design in this particular is bad the regulation will suffer, regardless of the excellence of the governor, as a time element will be introduced in which the water column will be accelerated or retarded, and during which the water-wheels cannot fully respond to the gate opening, on

PLATE XI.
PAPERS, AM. SOC. C. E.
JANUARY, 1903.
GERRY ON POWER TRANSMISSION.

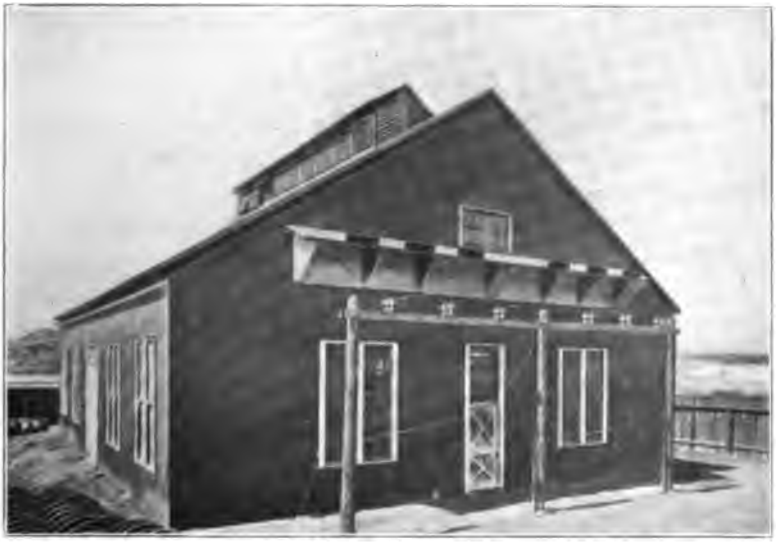


FIG. 1.—SUB-STATION AT BUTTE.

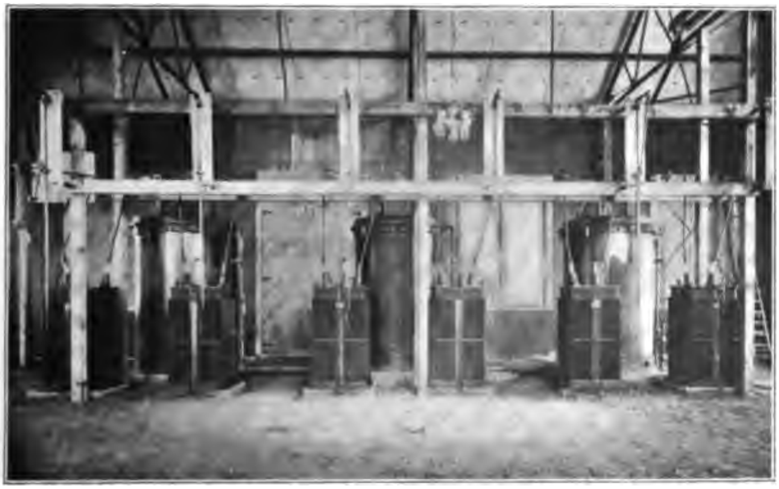


FIG. 2.—INTERIOR OF SUB-STATION AT BUTTE.

account of the varying effective head. One of the principal reasons leading to the removal of the old penstocks and the construction of the open canal at Canyon Ferry was to obtain better design in this particular, resulting in better speed regulation for the plant. The nearer the design approaches to an absolutely open setting, with the head entirely above the wheels, the better the regulation. From an inspection of the drawings it will be seen that the water passages from the canal to the wheels are very direct, and that the design approaches closely to the most desirable conditions. Next in importance, after proper hydraulic design, is a good governor, having ample power, and proper arrangements for relaying and returning the speed to normal at all points of the gates. It is also essential that the governors have a distinct speed characteristic, in order that the various wheels driving generators connected electrically in multiple may divide the load properly at all points of gate. If the governors do not have such a speed characteristic, the conditions will be unstable, and the wheels will shift the load between themselves, some taking more than others. The governor used in this plant is well known, and possesses the requirements mentioned. Besides a good governor, it is necessary to have a water-wheel with gates designed for easy control by the governor mechanism. Builders of water-wheels have given this subject considerable study, and great improvements in design have been made in this particular. The essential requirements are that the gates move easily at all points, and possess little inertia. The cylinder and wicket types of gate alone seem to meet these requirements for turbine wheels without seriously sacrificing efficiency. The new wheels at Canyon Ferry have cylinder gates, and the speed regulation does not exceed 3% under severe changes of load, and 2% under ordinary working conditions.

Of the operating electrical features, that of most general interest is the high voltage on the Butte transmission circuits. The electrical pressure is maintained regularly at 50 000 volts and more. This is a pressure higher than that used in regular commercial service elsewhere at the present time, within the knowledge of the writer. For many months a regular commercial service has been maintained at this pressure, and the results have been very satisfactory. Lightning, wind, rain and snow have not interfered with the regularity of the service. The electrical losses due to the pressure are trifling in amount and far less than the gain in other respects from the same cause. The behavior of these circuits does not differ greatly from similar circuits at lower voltages, and there are no luminous effects, or discharges, on the lines, under normal working conditions. A very satisfactory telephone service is maintained on one of the high-tension pole-lines.

The two transmission lines to Butte are generally worked in multiple, but each line has ample capacity for carrying the entire load, when necessary. In the operation of the plant it is customary to energize the lines separately from the station, and to synchronize and tie the lines together at the Butte sub-station. The overload switches and other special devices, already described, provide ready means for disconnecting any line or feeder, and any single unit or group of units of apparatus, either at the power-station or at the sub-station, can be put into service or instantly removed therefrom without affecting the service, or without the knowledge of the customers that anything has taken place.

The regulation of the electrical pressure is one of the most important factors in the successful operation of a transmission system. The maintenance of practically constant speed is, of course, a requisite. The generators should have good inherent electrical regulation, not only for changing load, but more especially for varying power factor. The electrical regulation of the transformers is of importance, but more especially is that of the transmission lines and feeders. The inductance, capacity and resistance of the transmission circuits can be controlled in design to a certain extent, and, if the nature and amount of loading are known in advance, the line regulation can be predetermined with accuracy. The nature of the load, especially as to its power factor, has a most essential bearing on the regulation. By uniting the various loads and working the entire system as a unit, there is obtained, under ordinary conditions at Canyon Ferry, a station power factor of about 90 per cent. The regulation at the Butte sub-station is within 5% of normal, under regular service conditions. The problems of electrical design and operation involved in this subject are complex, and are not within the scope of this paper, hence are not here treated mathematically or in detail.

At the generating station, the usual operations of starting, stopping, switching, paralleling and synchronizing are those common to all large power plants, and do not merit special description.

PLATE XII.
PAPERS, AM. SOC. C. E.
JANUARY, 1903.
GERRY ON POWER TRANSMISSION.

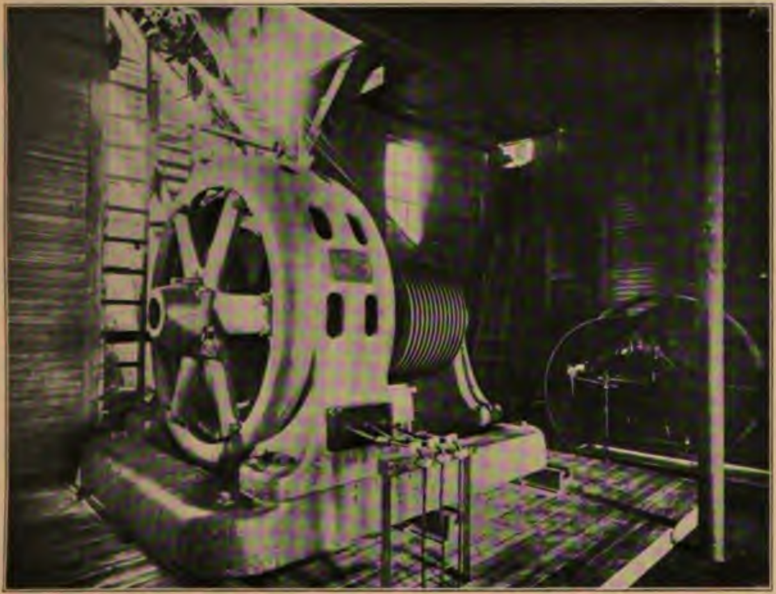


FIG. 1.—A 300 H.-P. INDUCTION MOTOR IN COLORADO SMELTER.

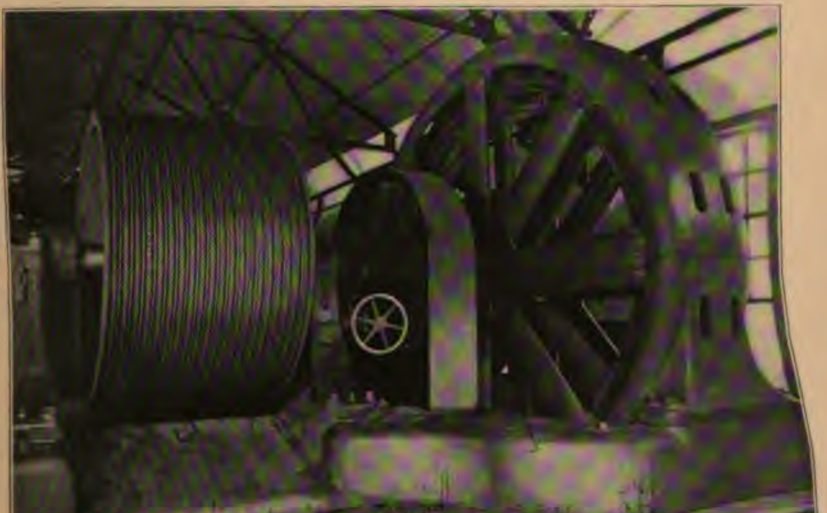


FIG. 2.—AN 800 H.-P. INDUCTION MOTOR AT ANACONDA MINE.

The writer desires to acknowledge the valuable services rendered, both in designing and construction, by his able assistants: James C. McKitrick, C. E., in charge of the general construction at Canyon Ferry; A. C. Pratt, E. E., in charge of the power-station machinery and electrical construction; Wm. L. Miller, E. E., in charge of the sub-station and all construction in the City of Butte; and Mr. E. E. Davis, in charge of all transmission-line construction.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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THE SANITARY DISPOSAL OF MUNICIPAL REFUSE.

An Informal Discussion.*

By Messrs. Rudolph Hering, H. de B. Parsons, W. F. Morse, George A. Soper, Theodore Horton and Elmer W. Firth.

Presented at the Meetings of December 17th, 1902, and January 7th, 1903.

Mr. Hering. **Rudolph Hering, M. Am. Soc. C. E.**—The subject herewith presented for discussion does not include the disposal of sewage. This has already received much attention and fairly satisfactory solutions. It embodies the treatment of the miscellaneous solid materials which are not removed by water carriage in underground channels, but require special cartage, and the best disposition of which is not yet generally recognized. The subject, in fact, is still under development, and, so it seems to the speaker, has now reached a stage where it requires the assistance of the civil engineer to bring it to a satisfactory state of practice.

For convenience of discussion, perhaps also of treatment, the materials included may be divided into four classes:

I.—Ashes;
II.—Street sweepings;
III.—Dry rubbish;
IV.—Kitchen garbage, swill or slop.

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* The discussion of this subject, for which no formal paper was presented, is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion. (See Rules for Publication, *Proceedings*, Vol. xxv, p. 71.)

Communications on this subject received prior to February 28th, 1903, will be published subsequently.

The problem before the engineer, therefore, is to effect a sanitary collection and disposal of these four classes of refuse at the least cost. For this purpose he must ascertain and carefully consider: Mr. Hering.

A.—The objectionable qualities of each class of refuse, viewed from a sanitary standpoint; which means the destruction of disease germs, the avoiding of a nuisance and the seeking of comfort and decency in the handling of this matter.

B.—The cost of collection—from the place of origin to that of final disposal—and the cost of final disposal, modified by any credit that may be due to a salable value of any part or parts of the refuse.

A.—SANITARY COLLECTION AND DISPOSAL.

I.—Ashes.—The objectionable feature in the collection and disposal of ashes is the dust. When placed on the sidewalk, when carted through the streets, or when dumped while the wind is brisk, the arising of dust is a nuisance.

The evident and simple remedy against dust, when collecting ashes, is the use of covered receptacles and covered carts, and, when disposing of them, is a careful and slow dumping, or, on special occasions, perhaps also a prior wetting.

The filling in of low ground is the usual way of disposing of this material permanently. Occasionally, it has been utilized as an ingredient for mortar or for road-making.

II.—Street Sweepings.—Street sweepings consist of horse droppings, accumulations of general city dust and dirt not separately removed, and earthy material worked to the surface of pervious pavements or brought by wheels from country roads.

The composition of sweepings, therefore, varies with the quantity and quality of traffic, the kind of pavement, and the distance from unpaved roads. The sweepings may contain a large or a small proportion of organic matter, some of which may break down rapidly and some slowly. The fineness of this material is its chief objection, as the wind readily takes it up and blows it about, to the injury of man, of beast, and of certain kinds of property. Germs of the most prevalent city disease, tuberculosis, may be abundant in the street dust, and the troubles of the continual warfare against this dust, when settling in the rooms of our houses, are known to all.

Sprinkling and sweeping at frequent intervals are the recognized, though often inefficiently executed, remedy against the dust nuisance within the city, and covered carts are also here required for the proper removal of the material.

Its final disposal can be effected in either of several ways. When mixed with fuel, and especially when containing but little inorganic matter, it can be burned, which destroys effectually the organic matter, Mr. Hering. including disease germs, contained therein; or, it can be dumped for the filling of low land, which can be quite satisfactory in many cases. When dumped, the upper surface of the fill alone remains exposed to the wind, and this only temporarily until vegetation protects it. When street sweepings contain a large proportion of organic ingredients, as horse manure, they are utilized as a fertilizing agent, with more or less success, and with the concomitant elimination of their objectionable qualities.

III.—Dry Rubbish.—The dry rubbish of a community consists of that aggregation of material which is not classed especially under the other headings. It consists chiefly of wood, paper, straw, leaves, rags, leather, stoneware, glass, metals, and sweepings from buildings. Its most objectionable qualities are dust and lurking disease germs. It is not easily decomposed, and its odor is but slightly offensive. Its value consists partly in the material that may be picked out, assorted and sold, such as metals, glass, and discarded articles of manufacture, and partly in the fuel constituents which it retains after such picking.

Its collection should be made in covered carts, to prevent odors, dust, and other nuisances. The frequency of collection is not an important question, due to the character of the material.

Its final disposition, after it has been picked over, is usually either as filling of land, by dumping, or as fuel, by cremation.

Filling up low land with this rubbish was an early practice, and still persists in many places. Where land is available, where such material will not cause future trouble, and where it cannot be burned economically, this practice cannot be seriously objectionable. Where the rubbish can be properly burned, such practice would generally be preferred by the medical profession.

IV.—Kitchen Garbage, otherwise called Swill or Slop.—Garbage proper is the refuse chiefly from kitchens, markets and slaughter houses, and consists almost wholly of rejected animal or vegetable matter in solid and liquid form. A large proportion, therefore, readily breaks down, and, on becoming putrescible, spreads offensive odors about.

It is the most important part of city refuse, both because it is likely to create the greatest nuisance, and because it has the greatest inherent commercial value. It has been the subject of more discussion, its treatment has been more varied, and a satisfactory solution of the problem of disposal is less generally acknowledged, than in the case of the other classes of refuse.

Regarding the best manner of collecting this material, there is but little question. It is generally conceded that it should be placed in water-tight and covered receptacles, and collected in water-tight and covered carts or wagons. It is also conceded that the collection should be frequent. The frequency, however, varies often with the

Mr. Hering.

density of population. Yet this density affects only the quantity of the material, not its liability to putrefy, which is controlled wholly by its composition, the length of time it is exposed, and by the temperature. That the latter fact is beginning to be recognized in some cities is evidenced by ordering more frequent collection in summer than in winter. The necessary frequency should also vary with the manner of disposal. If, for instance, garbage is fed to swine, then, for sanitary results, a daily collection is peremptory throughout the year, except only in very cold weather.

In northern climates, where winters are cold and long, the receptacles, for obvious reasons, are better made of wood than of metal, while in warm climates the reverse is true, which conclusion is already recognized occasionally. Where garbage is likely to freeze while waiting for a collection, a conical-shaped receptacle is the only proper form.

The final disposition of this material is now being effected in the following ways:

1.—Feeding to swine,
2.—Dumping as filling,
3.—Dumping into large volumes of water,
4.—Ploughing into soil,
5.—Extracting the grease,
6.—Cremating the organic matter.

Feeding to Swine.—This was one of the first methods of disposal ever used, and it is still practiced extensively. In New England it is the prevailing method in small and medium-sized communities. If kept free from other refuse, and from such as would injure its food quality, if collected and properly delivered daily, there seems to be no serious objection to this method, either from a hygienic or commercial standpoint. It has an advantage over all other methods in yielding a revenue from its sale, which is sometimes greater than that obtained through any other method of disposal. Its application, however, must be confined to conditions under which the sanitary quality of the food, respecting disease germs and odors, can be safely guarded and maintained, and which excludes it from adoption in large cities, except in the case of hotels and eating-houses, where a private collection can be secured.

Dumping as Filling.—This is practiced in places where feeding is found objectionable. When not mixed with other refuse, dumping is objectionable on account of the subsequent putrefaction, in case of a large accumulation of the garbage. When mixed with other refuse, the merits of dumping depend on the proportions of the ingredients of the mixture, and on the character of the locality where dumped. Under some conditions a nuisance would, and under others would not, result.

Mr. Hering. *Dumping into Large Volumes of Water.*—This method can, or cannot, be advised according to the special conditions of the case. Like the disposal of sewage by dilution, a safe disposal of garbage can be effected by dispersion, if the quantity of water is sufficient, if the current or winds prevent a drift ashore, and if the sinking material does not accumulate so as to reduce the necessary channel depth for navigation, or produce foulness by deposit on shallow areas. Opportunities for a satisfactory disposal in this manner will be rare.

Ploughing into Soil.—This has been practiced with varying success. If freed from metals and large entangling objects, and if mixed with barren sandy soils or acid soils, garbage being somewhat alkaline, good results have been obtained for the raising of crops under careful management. This process is at present considered favorably in several cities of Europe, because it can dispose of disease germs and odors satisfactorily, and because its gradual nitrification has produced a fertile soil where sterility had previously prevailed.

Extracting the Grease.—The extraction of grease from garbage is an American industry which has been promoted in a number of our cities. The process in its general form consists briefly in separating the material into two parts, each having a salable value, namely, oil, or fat, and a dry, stable, fibrous material of vegetable and animal origin, called tankage, and used as a filler or diluter for certain fertilizers. The separation is brought about by simple boiling and subsequent pressing out of the oil and water, which are in turn separated by gravity. Or, it is accomplished by an admixture with naphtha, which dissolves the oil, and later, after it is separated from the tankage and cooled, enables it to be readily extracted. The water separated from the oil is an offensive liquid, and the gases and fumes generated at the works are offensive vapors. Both require a careful and thorough treatment.

The objections to this reduction method of garbage disposal, which is still practiced in Boston, New York, Buffalo, Philadelphia, Washington, St. Louis, Cincinnati, etc., although abandoned in some cities, is due to the offensive odors occasionally, if not continually, arising from the same. The process requires the rejection at the works of tin cans and other foul material which interferes with the economical process of securing the oil. For such rejected material a different treatment and disposal is necessary. While, from an engineering point of view, it is practicable to construct and operate these reduction works so that odors will not prevail, the means for doing so are also expensive. As they are operated invariably as a business undertaking for profit, the conflicting interests naturally involve the constant danger of a possible nuisance. The practical result has been that, for the sake of sanitary security, such works are now placed as far from inhabited territory as practicable, with the disadvantage that the distance for transportation has become correspondingly greater.

The advantages of this method lie chiefly in the commercial value of the oil and in the destruction of disease germs and putrescible matter by heat. There is little value in the tankage, which is occasionally used as a fuel or even wasted on dumps. Mr. Hering.

After all the operations of a reduction process have been conducted without offense, the financial aspects will decide the permanent merits and value of this method of disposal.

Cremating the Organic Matter.—This is the favorite and exclusive method of garbage disposal in England, where it has been used for fifty years; and it is also the favorite one of the medical profession. In the eyes of the sanitarian the complete destruction by fire of all matter that may become offensive, and at the same time of all disease germs that may lurk in the sweepings of the house and in the rejected food materials, is an ideal process.

In practice, however, the results have not always been ideal. In our country odors from such works have been complained of in many instances, and a number of crematories have been abandoned as nuisances. In England, however, such has not been the case. Furnace extensions are built every year. Complaints are rare. In Hamburg, Germany, where is the largest single garbage crematory in existence, this is giving no offense, although adjoining a built-up section.

An examination into the reasons for the different results achieved by cremation in Europe and America shows that the elements making up the problem are not the same.

1.—The material as it is burned in Europe has not the same composition as that which here has failed to burn properly. European success was achieved with refuse generally consisting of a mixture of garbage with ashes and dry combustible rubbish. The chief failures in America are recorded where garbage alone was cremated, without the admixture of other combustible dry refuse, and even after the addition of furnace coal. An examination into the combustibility of European and American combined refuse does not show a great difference. The few analyses we have show that cremation under proper precautions and suitable conditions should be as practicable here as in England, and recent furnaces built here demonstrate this fact.

2.—The essentials in the construction of the successful English furnaces differ from those of the furnaces peculiar to our country, where they have not been satisfactory. The English furnaces are built with sloping grates of small area, while the American furnaces generally have horizontal grates of large area. It is hardly necessary here to point out that in this element lies a main defect of our plants. A sloping grate admits of an almost automatic continuous process of gradual drying, then heating, and finally burning; the fresh material being added at the upper end and the hottest fire being near the lower end. A horizontal grate, on the other hand, to secure proper combus-

Mr. Hering. tion, depends almost wholly upon stoking, which causes the burning to be irregular, due to the sudden dropping of cold and perhaps wet material upon that which is already almost completely burned. In Europe we also find an extensive use of large dust chambers to prevent the escape of this fine material, of which we so often hear complaint. We find also a more frequent and effective placing of dampers to control the draughts, and thus prevent the escape of unburned, and therefore odorous, solid particles and gases. Finally, more attention is directed there than here to the evolution of the greatest possible heat for the incidental production of steam.

3.—The expert garbage fireman, who is considered essential to success in England, is generally supplanted here by a man whose only qualification for the position may be that he can shovel coal or pull out clinkers, but generally has not the remotest knowledge or even conception of the difficulties in burning, on a large scale, both continuously and completely, the most heterogeneous mixture of all forms of solid matter to be gathered from a modern community. The advantage of a trained expert in firing city refuse was well shown by the fact that until Hamburg imported English firemen to train the German firemen in the mere operation of their own plant, satisfactory results could not be obtained.

4.—In Europe, the municipalities, under the guidance of experienced engineer officers, generally undertake the cremation by their own long-trained employees, while here usually either the health boards or council committees select not only the design, but indicate the method of operation, appoint inexperienced employees, or enter into a contract for immediate profit rather than for permanent efficiency. The difficulties underlying the problem of city refuse disposal, which is almost wholly one of engineering, have been solved satisfactorily where competent engineers have been employed for the purpose. It is hardly to be expected that, without professional skill and training, desirable results can be reached in this, any more than in any other, branch of engineering.

It will therefore rest finally upon our profession to solve this urgent question in our country, by not only making the necessary preliminary investigations to determine the most economical means of disposal, to indicate the methods, and to design the works that will accomplish this in a sanitary and inoffensive way; but, also, by indicating the details of operation most suitable for the particular kinds of material delivered.

B.—Cost of Collection and Disposal.

In discussing this subject, in full view of what has been said regarding the sanitary demands, we are now able to add that the latter demands can be satisfied by the engineer in any and all of their aspects if the necessary price is paid. He is therefore obliged to estimate, here, as in his other problems, the cost of each method, developed to a point of satisfactory efficiency. The least expensive of the several possible methods will then become the preferable one. As the question of cost embodies the collection, from the point of origin to the point of disposal, the estimate must embody the expense required between these two points; for one process may require a much longer haul than another; then, to be economical, the disposal in the first case must cost proportionately less than in the second. Mr. Hering

Theoretically, it would be proper, in a given case, first to estimate the cost of properly collecting and disposing of each class of refuse, separately, in accordance with the several practicable ways indicated. Then it might appear that perhaps some two or three or all four classes of refuse could be treated economically by the same process. In this event a second estimate of cost would be appropriately made for a system of combining the collection and disposal of two or more such classes of refuse, and thereby the expediency of a system of separation or combination, in part or as a whole, would be ascertained. In practice, this procedure sometimes might be very simple.

In making such estimates of cost it is necessary to take account of both debit and credit sides of the financial aspect.

The collection is a debit in every case, its amount depending upon the distance the refuse is hauled. When garbage is fed to swine, the collection should be more frequent than in other cases, and a further debit would be proper on that account.

The final disposal has both debit and credit sides to be investigated. In the case of kitchen garbage and dry rubbish a substantial debit is required in establishing preventive and precautionary measures against the arising of offensive odors, of dust or other nuisances, in whatever process of disposal may be considered. On the other hand, the credits must be determined, as the case may be, and, if found to exist, they may be given to the several classes of refuse as follows:

Ashes.—By filling land, utilization for road-making, or as an ingredient of mortar, or otherwise.

Street Sweepings.—By making land or by utilization as manure, or otherwise.

Dry Rubbish.—By utilizing whatever value exists in the pickings, and in the remainder as fuel for power purposes.

Kitchen Garbage.—By utilizing its value either as food for swine, as grease and fertilizer, or as a heat producer for power development.

If the subject under discussion is treated substantially as above outlined, the speaker believes: First, that, through the co-operation of the engineering profession, it will gradually cease to be a vexed question among our legislators; secondly, that the sanitary demands, in preventing nuisances and dangers to health, will be satisfied; thirdly, Mr. Hering. that the economical advantages inherent to the several processes will be secured; and fourthly, that the result will be an efficient process operated at the lowest cost.

Mr. Parsons. H. de B. Parsons, M. Am. Soc. C. E.—The primary collection of the refuse of a municipality is made by carts, which convey the waste material to points for final disposition. This primary collection presents no special difficulties. It is a matter of carefully working out the details to suit best the existing conditions.

The problem that is serious and difficult to solve is that of the final disposition of this refuse—a problem which is closely allied to the health of the community. The direct benefits derived by a suitable system for sanitary disposal are augmented indirectly by an increase in the health of the community.

No matter how the question is approached, the practical considerations of first cost and expense of operation and maintenance will be found paramount. On this account, as well as the short tenure of office of our city authorities, systems have come into use which are neither the most sanitary nor most economical for final disposition. Contracts have been let for such short periods that contractors have refrained from erecting suitable plants, and systems have been evolved which only earn for the cities a portion of the direct returns that might be obtained.

The refuse of a municipality consists of garbage, ashes, rubbish and street sweepings. In an average American city the divisions are proportioned approximately, as follows:

	By weight.	By volume.
Garbage	13 per cent.	18 per cent.
Ashes	80 "	57 "
Rubbish	7 "	25 "

The statistics gathered from one city are not applicable to another; and results predicated on information obtained from other places will not always be satisfactory. In order to make a final solution of the problem, it is necessary to study the conditions obtaining in the particular place under consideration. Garbage is combustible. It is extremely difficult, however, to burn pure garbage, and it has been found necessary to mix fuel with it in order to obtain complete combustion. The amount of fuel required varies from 8 to 20% of coal by weight, according to the character of the place and the constituent elements of the garbage. Ordinary kitchen garbage consists of approximately, by weight:

Animal and vegetable matter	20 per cent.
Grease	3 "
Water	70 "
Rubbish, cans, rags, etc	7 "

Mr. Parsons.

Ash collections are divisible into two kinds, steam ash and household ash. The steam ash, produced by manufacturing companies, comes to a city dump practically pure. It is clean and contains little unburned coal. The household ash, on the contrary, contains a large quantity of unburned coal. It has been estimated that, in a city like New York, the quantity of unburned coal in the ash carted to the dumps from private houses and apartment houses amounts to about 20%, and, in the speaker's experience, there is little question but that the proportion is correct. This coal, mixed with the ash, can be and is utilized as fuel to assist in the combustion of garbage. The ash collections make a good filling material, and can be disposed of for that purpose.

Rubbish collections are very combustible, as are also the street sweepings.

Final disposition of the refuse may be made, first, by dumping on waste lands, or at sea; secondly, by sending the garbage to reduction works, cremating the rubbish, and utilizing the ash collections for filling; and, thirdly, by cremating the garbage and rubbish, and utilizing the ash collections for filling.

The first method is neither sanitary nor satisfactory.

The second method is sanitary, but not wholly satisfactory. The reduction works can only handle garbage, and the system is considered uncertain in case of an epidemic, as the employees might refuse to work the plant. Such works can only afford to operate on a bonus paid by the city. The process consists of extracting the moisture by pressure, as being cheaper than evaporation, and of cooking the material by steam in large tanks or digesters. The products are grease and a residue sold as fertilizer. The plants are expensive to construct.

The third method is sanitary, and, in the speaker's judgment, the best; because it has been accomplished without creating a nuisance, because it is the most sanitary, and because it can be made to produce the greatest revenue. To be successful the combustion must take place at a high temperature, say between 1 500 and 2 000° Fahr. The household ash, the rubbish and the street sweepings will supply the fuel.

Cremation has been tried, in a number of places in America, with poor results, although very successfully practiced in Europe. The failure in American cities has been largely due to faulty design of the furnaces, lack of high temperature (a most essential feature), and want of means for properly caring for the garbage when first brought to the destructor. When garbage is allowed to collect in mass, it is most highly objectionable, and such collections have caused, in some instances, the failure of what otherwise might have been a successful plant. The heat generated can be used for various purposes and be made income-earning.

Mr. Parsons.

CONDITIONS IN THE CITY OF NEW YORK.

Area of Greater New York	320	sq. miles.
" " Borough of Manhattan	39	" "
Paved Streets, Greater New York	1 000	" "
" " London	1 818	" "
" " Paris	604	" "
" " Berlin	500	" "

The amount of refuse collected yearly in the Boroughs of Manhattan, Bronx and Brooklyn is about 2 800 000 tons. The collections, in pounds per capita per week day, are about as follows:

Garbage	0.4 lbs.
Ashes	2.5 "
Rubbish	0.3 "
Street sweepings	0.7 "
Total per capita per week day	3.9 "

Comparing this record with other cities, of which the records are believed to be fairly accurate, the following comparison is made:

New York	3.9 lbs. per capita per day.
London	1.6 " " "
Berlin	0.9 " " "

Results varying so widely show the difficulty in predicting what can be done with a municipal refuse, unless one knows in advance the character of the waste.

The rubbish collections in New York City weigh, on the average, about 250 lbs. per cubic yard. In Boston they weigh about 202 lbs. per cubic yard.

These rubbish collections have been divided as follows:

	By weight.	By volume.
Combustible material	60 per cent.	37 per cent.
Incombustible material (valueless)	5 " "	3 " "
Marketable material	35 " "	60 " "

The rubbish is picked over at the dumps by a trimming contractor, who pays the city for the privilege. The value of this marketable material to the city is about $3.20 per ton. The Commissioner of Street Cleaning has stated that this figure is too low; probably it should be increased 50 per cent. It is figured as follows: The average rubbish collections are 300 tons per day, or 1 800 tons per week, of which the marketable or salable material is 35%, say 600 tons. For this the contractor pays the city approximately $1 920, or at the rate of $3.20 per ton.

The present Commissioner of the Department of Street Cleaning had an incinerating plant* constructed, from designs by the speaker, at the city dump at the foot of West 47th Street, Borough of Manhattan. Mr. Parsons.

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* Illustrated in *Engineering News* and in *The Engineering Record*, in April, 1902.

The record of this incinerator is as follows: The number of loads of rubbish brought to the incinerator per day—maximum, 80; minimum, 20; average, 44.2. The 44.2 loads per day weigh about 61 000 lbs., or 30.5 tons. Of this amount about 75%, or 22.87 tons, was consumed; 5%, or 1.5 tons, was incombustible; and about 20%, or 6.1 tons, was trimmed. Much more than 20% could have been trimmed, but the incinerator burned the material so fast that the contractor did not have time to separate it out.

The incinerator contains a grate surface of 90 sq. ft., and the stack is 120 ft. high. The average weight of the material consumed per hour is 5 720 lbs., or 63.5 lbs. per square foot of grate per hour.

The design of the incinerator, in brief, consists of three cells, each having 30 sq. ft. of grate area. The products of combustion pass over the cells into the smoke flue in such a manner that the product from Cell No. 1 has to pass over Cells Nos. 2 and 3; the product of combustion from Cell No. 2 mixes with the products from Cell No. 1 and together they pass over Cell No. 3; and that from Cell No. 3 mixes with the products from Cells Nos. 1 and 2 and is intimately mixed again in passing along a tortuous flue to the base of the stack The result of this arrangement has been highly satisfactory, as regards the non-production of smoke. Taking a stormy day when the material was brought to the incinerator wet, the smoke was seldom visible for more than about 75 ft. from the top of the stack, and then only during the period of stoking one of the grates.

This incinerating plant was constructed as an experiment. In order that it might be free from any hindrance by injunction or otherwise, lest it create a nuisance to neighboring property, it was decided to locate the plant on one of the city piers, about 250 ft. from the bulkhead line. The permanency of location, of course, was not considered, the idea being that if the plant could be constructed quickly and show that combustion could be carried on without creating a nuisance, it would lead to the introduction in the future of other stations, more favorably situated, and at which better facilities could be provided for the reception of the material and for the picking of the same.

The incinerator, thus far, has proved satisfactory, and the Commissioner has authorized the preparation of plans for further developing its capacity.

An analysis of the cost of incineration compared with removal of material by scows is as follows:

First, the Final Disposition by Scows, as Formerly Practiced.—Assuming the same figures as now obtained at the incinerator, namely, 30½ tons of material per day, on the average, the cost of removal of that material, figured at 15 cents for towing, and two days' hire of the

Mr. Parsons. scows, (one for loading and one for towing) at 23 cents, comes to about 38 cents per ton. Owing to the bulkiness of rubbish, only about one-half tonnage can be put upon a scow, the tonnage being figured by volume, which makes the disposal of the material come to something like 80 cents or more per ton by weight. Therefore, 24.39 tons at 80 cents cost the city $19.51 for removal. The 6.1 tons, making up the 30.5 tons, which is saved by the trimmers, at $3.20, also figures $19.52; thus, practically, the cost of removal by scows was offset by the receipts from trimming.

Second, by Incineration.—The result is approximately as follows: Received from trimming 6.1 tons at $3.20, $19.52 per day. Received from the city ash collections, which at this dump amount to about 600 tons per day, and which are made salable at, say, 5 cents per ton when freed from the rubbish, $30.00. Total receipts to the city, $49.52. The cost to remove the incombustible material, 1.5 tons, at 38 cents, 58 cents; cost of burning, interest and repairs on the incinerator, estimated, at $7 per day; labor, feeding and firing, four men, $10 a day; ash removal, $1 a day; total, $18. Net gain, therefore, to the city, $30.94 per day; yearly gain, more than $9 000.

The incinerator, at these figures, will pay for itself within two years. According to the figures quoted by the Commissioner, namely, 19 cents a ton for the ash collections, would make a daily revenue of $114 from the ashes, in place of $30, or a net gain of $114.94 per day, or more than $34 000 per annum; at which rate the incinerator would pay for itself in less than six months.

The ashes produced by the incinerator are very light, completely burned, and, owing to the large quantity of wood from which they are produced, have some value as a fertilizer, and are used by the Park Department for spreading on lawns and around trees.

The improvements referred to are an unloading floor and a belt conveyor, which should increase the amount of material trimmed, that is, the marketable material; and should reduce the cost of labor. Probably the services of two of the men now required could then be dispensed with.

Mr. Morse. W. F. Morse, Esq.—For twelve years the speaker has been actively engaged in the work of final disposal of municipal refuse. It has been his province to present the question in many places and in many ways, and, until now, it must be candidly said that it has not met with appreciation or attention on the part of the engineering fraternity. It has been a question which has fought its way, despite opposition, has been in the hands of men and committees who were really unacquainted with the subject, and has consequently been approached from the standpoint of an endeavor to solve an engineering question without the benefit of the best engineering skill.

The whole subject is a very wide one; it cannot be treated in a short way—by a short discussion—it has to be taken piecemeal and dissected, each part separated and treated by itself. Mr. Morse.

The remarks of Mr. Hering cover the whole question in a general way. He has given an outline of the various methods of collection, of the disposal, and of the results obtained. The remarks of the Commissioner of Street Cleaning and of Mr. Parsons cover the work done in New York, but there are many other cities than New York investigating this matter, and it is of much wider scope than the limited field of a single city.

In the limited time allowed it is possible to deal with the question only in a very general way, and to give a brief sketch of what has been done in the past ten or twelve years in this country, and, in comparison with that, an idea of what has been accomplished abroad.

Municipal waste has been divided into four classes: garbage, street sweepings, ashes and refuse. The disposal of all these is accomplished by two methods, or systems: reduction and cremation. Reduction, or the treatment of garbage only for obtaining a commercial product, is not now under discussion; but it may be said in passing that this method has been adopted by several of the larger cities, has cost large sums of money to establish, and is yet at a stage where it is impossible to say what its future will be. It is only known that companies and men are putting large sums of money into reduction processes, and that, so far, as many plants have failed and have been abandoned as have succeeded.

If a city is investigating this subject with a view to the disposal of all its waste, and if it adopts a means of disposal which treats only one-tenth of it, there is manifestly left on its hands the remaining nine-tenths. Reduction deals with only 10 or 12% of the whole collected waste of the city, treating garbage only. Cremation, on the other hand, takes the whole collection of miscellaneous waste and disposes of it all.

There have been in the United States, in the last twelve or thirteen years, something like seventy-five or eighty places where cremation has been adopted. This work was begun in Des Moines, Iowa, about fourteen years ago, by a furnace invented by Mr. Andrew Engle, and from which have come all the forms of the American cremator, all more or less imitations of the original Engle type. It is a structure of rectangular form, having an upper chamber and transverse bars on which the garbage is deposited. The fire is at one end, and in most cases the secondary fire for burning the gases is at the other end. In all cases of American crematories two fires have been found necessary, and that principle has been maintained in constructions of this type.

About a month ago, an article appeared in one of the prominent municipal journals under this caption: "Why do American Crema-

Mr. Morse. tories Fail?" The text of that article was a report, made by a leading engineer of this Society, upon a furnace built in a neighboring city, and which was reported to be working unsatisfactorily. In the main essentials, that article is true, and, after twelve years' experience in building garbage furnaces in this country, the speaker is in a position to say that satisfactory progress has not been made; that while one or another type of furnace after the American pattern has been built and has performed its functions, and may be still doing so, the retrogression—that is to say the abandonment of furnaces which have been built after these patterns—has kept pace with the number installed. Therefore, comments, by the newspapers and by prominent engineers, to the effect that the progress of the disposition of waste in this country is not satisfactory, are absolutely true.

Beginning fourteen years ago, with that form of American cremator which was shortly after imitated by other constructions, there have been seventy-five built, and of these perhaps the most widely known and successful installation of the American type was made at the World's Fair in Chicago. This was a case where it was expected that some 50 or 60 tons of refuse per day would be handled, also the sewage sludge which could not be disposed of in any other way. Furnaces, after an improved Engel pattern, were built, and were run six months without intermission, using oil as fuel, and destroying on the grounds of the Exposition, within the confines of one building, all the garbage and all the sewage sludge caused by the presence of 27 500 000 persons, without sanitary nuisance, and to the entire satisfaction of the authorities.

That is an example of what might be done under the best conditions in which an American furnace could work, but that example was never improved upon. The furnaces so built were offered as a gift to the City of Chicago, but they were declined on the ground that they were placed on public property, under control of the State, not the City, and could not be accepted by the City. The results of that demonstration in Chicago show that under proper conditions garbage containing a large percentage of moisture and sewage sludge (two of the most refractory things in the world to deal with by fire) could be destroyed by maintaining a sufficiently high temperature and providing combustion chambers for the destruction of the gases. Unfortunately, this example was never carried much further by that company, but it was acted upon by others, and has been repeated since; yet, in spite of the lessons taught by ten or twelve years of experiment, it may be said that the progress made in cremation work has been equalled by the retrogression in the same line; that furnaces are abandoned about as often as they are built.

There are several obvious reasons for this. The work has been begun at the wrong end. At the outset, a sufficient amount of engineering skill was never applied to it. Municipal committees have **Mr. Morse.** gone about the country and have been persuaded by ambitious furnace builders to install plants. These plants have been simply experimental—built for a profit. They were not durable, and required extensive repairs. In many cases they were not sanitary; they emitted odors; they were not in all respects adapted to the work required of them, and they were expensive to operate. Yet, with all their defects, they have made for progress in one particular: they have directed the attention of the people to the fact that something is needed.

At the present time there are four or five companies constructing garbage crematories with varying success in different parts of the country. There are at least ten or twelve firms who have gone down—in other words, who have constructed furnaces found to be inefficient—and we are at a stage of the general question of cremation where it is necessary to have some more efficient means brought forward. If progress is to be made, it must be made either by inventing a new furnace, or by adopting other furnaces which have been proven successful elsewhere.

The question arose in England twenty-five years ago, long before it was ever thought of here. It began by the construction of the cell furnace, so-called, the Freyer destructor, operating by the use of a natural chimney draught, no forced draught being thought necessary at that time. The results were almost identical with those of the American furnaces of to-day. The temperature was low, offensive gases were thrown off, notwithstanding the "fume-cremator," or secondary fire, and it was found expensive to maintain. No real progress was made until about four or five years ago, when the furnace was shortened, forced draught introduced, the sloping platform made in such a shape that the garbage could be used as part of the fuel, and a combustion chamber added, behind which a steam boiler was placed.

The English destructors are to-day one of the most powerful agencies for sanitary conditions in England. They take what is known here as municipal waste, as a whole. No separation is made; the entire waste of the household goes into what is called an ashpit, or ashbin—garbage, refuse and ashes—and this is taken directly to the destructor and burned. It is destroyed under forced draught, with no other fuel needed than the material itself. The result is the production of a volume of heat which operates steam boilers of very great capacity, the power from them being utilized for the production of electricity, for pumping sewage and water, and for many other municipal purposes.

The comparison between English and American efficient disposal work is distinctly against us. We are doing as they did six or eight years ago. At the present time there is no English destructor on this

Mr. Morse. continent. The Thackeray furnace is an attempt. It is really an imitation of the principles of the Freyer destructor which was built many years ago in England, and which has now almost passed out of date, being supplanted by more powerful ones. There are two examples of this furnace, one in Montreal and another in San Francisco; but in the last five years, since these furnaces were built, no others have been installed, and there has been little attempt to develop more fully the English ideas.

The chief reasons for this lie practically on the financial side of the question. The cost of the construction of a destructor is about one-half more than the cost of an American cremator of equal capacity, and municipalities are usually looking first to the dollar and second to the sanitary operation and to the comfort of the people.

The following figures are quoted from the latest information regarding the operation of the English destructors. The comparative results from twenty English destructors, of eight different types, with thirty-two tests made for evaporation at different periods, shows that the average combustion per square foot of grate surface is 47 lbs. of mixed waste, garbage, ashes and refuse, and the evaporation of 1.36 lbs. of water for every pound of waste consumed. Therein lies the secret of the progress made in England. When they put into their destructors a mixed mass of material and burn it under a forced draught and develop steam power which is equivalent to the evaporation of 1¼ lbs. of water for every pound destroyed, the enormous force produced can readily be seen, the utilization of which has made it possible for every municipality to do its work with its own power, without other fuel than the material destroyed, at a very small cost as compared to the cost of operation on this side of the water.

The cost of labor for destroying a ton of mixed refuse will run from 12 cents to 30 cents per ton, dependent upon local conditions. In one place the work is carried on at a profit; in others, the returns from the destructor, in steam power and in products manufactured from ashes, pay all operating expenses and fixed charges. The residuum from these furnaces is a valuable asset. The clinker is ground up and made into mortar, or tiles, paving blocks and brick.

There is another item on the credit side of the destructor, that is the utilization of power developed by the combustion of municipal waste for use in electricity works.

There are about 160 places in Great Britain in which destructors are used, and more than two-thirds of these utilize the power for various purposes. The electric force developed by a destructor which burns the waste product of a city is equivalent to 30 British Board of Trade Units per ton of waste destroyed. If it be assumed that each unit is equivalent to 280 candle-power, the result is something like 8 400 or 8 500 candle-power from each ton of waste.

The chief reason why advance in disposal work in that country has been so rapid and efficient is the fact that English municipalities proceed upon a different plan from ours. They make it a part of their municipal work. In this country it is contract work, and, consequently, there is not the same opportunity for cities to develop along the lines of municipal ownership and administration. There is a strong desire on the part of municipalities to adopt these improved methods, but they are held back by the fact that in almost every case the contract takes precedence, and the contractor is desirous only of getting through with his contract, and the same results are not accomplished as when the work is done by the municipality. Mr. Morse.

The remarks made by the Commissioner of Street Cleaning and by Mr. Parsons upon the work in New York City are pertinent and apropos of the question, but they do not cover the country. The principles which Dr. Woodbury is carrying out were instituted by Colonel Waring five or six years ago, and the experiments made at that time showed conclusively that the value of the rubbish of New York City was greater by far than anyone had supposed. The statement made by Colonel Waring in one of his last reports, that the value of the refuse, garbage and ashes of New York City would, if properly utilized, pay one-half of the total expense of cleaning the city, has never been realized. Yet it is certainly a question which is being answered by the present administration in a very satisfactory way. The Commissioner has alluded to, and Mr. Parsons has described, an incinerator, for the conversion of refuse, at West Forty-seventh Street.

The speaker had the honor of presenting this question to the Mayor of Boston four and a half years ago, proceeding largely upon the lines marked out by Colonel Waring, and at that time it was believed that the utilization of the refuse would become a feature of very great importance in municipal work. Mayor Quincy looked into the matter personally. He called for specifications and bids; he obtained four or five bids which were unsatisfactory, and rejected them. He took the plans which were offered for the construction of an incinerator in Boston, and caused it to be erected by a private company. The incinerator is quite different in pattern from the one described by Mr. Parsons, but for four years it has been burning the refuse of the business section and a large part of the residential portion of the city, taking the waste from about 200 000 people, covering about 95 miles of streets, brought to one central point. The waste is carried into a room and dumped upon a moving platform, or belt, 150 ft. long, and during its passage the refuse is picked over by men placed on each side. These sorted portions pass into bins and presses below, and the remainder is discharged automatically into a destructor, or incinerator, placed across the end of the building. The quantity of waste destroyed began at about 25 tons per day for the first year, and it has increased

Mr. Morse. until now about 40 tons per day are collected and disposed of. The product which is picked out from the refuse by these men will reach very nearly 60% of the whole bulk. It is divided into six or seven classes of paper, five kinds of rags, rubber, glass and iron. Everything possible is sorted out and saved, and the residuum destroyed are the small, worthless portions of paper, excelsior and straw, and a small amount of wood. The operation is conducted precisely as it should be conducted in New York City, in a closed building, the city carts discharging their loads out of sight of passers-by, no nuisance of any sort being connected with the work. After baling, the salable portions are at once conveyed to market, and the power produced by the combustion of the worthless portions of the refuse drives a 60 H.-P. boiler to its utmost capacity, which in turn moves all the machinery, lights the building with electric light, removes the ashes, heats the building in winter, and, thus far, has furnished a surplus of steam power.

The operation of this plant for four years shows that the refuse of a city of the size of Boston is more valuable than almost any other part of the municipal waste, and that every city with a population of 50 000 or upward can easily turn its refuse into money which will go a long way toward paying the expenses of the whole collection service.

Other cities are considering this question, with the idea of bringing into use a system similar to that which has been carried on in Boston, and which has just now been reinaugurated by the Commissioner of Street Cleaning in New York City, and which will undoubtedly be a factor in the disposal work of all cities in the country.

The average quantity of refuse collected is about 1 ton per day for every 10 000 persons. It may be more or less according to the different character of the city and the population, but it is of sufficient value to pay for the installation and operation of a plant in any one of the larger places in the country.

The future of this question depends upon utilization. American crematories have been going on for ten years, destroying garbage by using coal. The builders, up to this time, have paid no attention to refuse and its salable and fuel qualities. They have allowed the heat produced by the combustion to go to waste; and they have not been over-desirous of guarding against sanitary nuisance, but have sought to destroy the waste in the shortest possible time, without considering the economical points involved.

There is a general impression that a change must be made before real progress can be had, and there is hope that the engineering profession throughout the country will take up this question, as has been done abroad, and bring its trained experience to the assistance of the municipalities, solving the question in a much shorter and easier way than it can otherwise be done. It is inevitable that this will come about. The men who are trained in constructive and operative work should be the ones to decide what shall be done in this line by every city. Mr. Morse.

There is another side to this matter which is pertinent to the question under discussion. That is the disposal of the waste of large isolated buildings, like public institutions of every class, hotels, business establishments and even individual dwellings. The quantity of waste produced in these places is proportionately larger than under other conditions. There is now in use a form of destructor, installed usually in the basement of the building, connected with the boiler breeching, or the chimney. These destructors are used for the disposition of every class of waste, including that from laboratories and medical colleges.

The latest examples of these furnaces have been built in connection with the steam boilers of large business establishments, where the heat from the enormous mass of waste destroyed is used as auxiliary for operating the boilers. In some cases the destructor is also provided with a separate steam boiler operated by the furnace, but supplied with its own fire box, the power from which is utilized for specific purposes, like running elevators, or in connection with the low-pressure steam system of the building.

The advantages to be obtained by the introduction of these local destructors are the disposition of the waste on the premises in a perfectly sanitary manner without the necessity of storing and handling the same, and the development of a certain amount of steam power, resulting in the saving of coal, or other fuel, and to some extent expense in steam boiler equipment. These destructors are also being adopted by the Government for use in Army and Navy posts and government buildings throughout the country.

The number of these destructors in use, already quite large, is increasing rapidly, as the installations are made under the direct inspection and by the advice of competent architects and engineers engaged in the construction work.

George A. Soper, Assoc. M. Am. Soc. C. E.—The question of the sanitary disposition of municipal wastes is often divided into two parts: Final disposition, and collection. Mr. Soper

By final disposition is meant the utilization or simple deposit of wastes; and by collection is meant all other steps in the operations of a street-cleaning department. It is not uncommon, in discussions on this topic, to omit that part of the subject which relates to collection; but, as the two questions are inseparably related in practice, it seems desirable that they should be treated jointly.

To a large extent, the method chosen by a city for the final disposition of its refuse is a controlling factor in the organization and plant of its street-cleaning department. This has been so in New York City.

Mr. Soper. The history and development of the Department of Street Cleaning in New York City affords many interesting suggestions as to the relations between final disposition and collection, and the experience of that city furnishes, withal, such an instructive illustration of the need of keeping the various parts of the machinery of the street-cleaning department in harmony and up to the requirements of a rapidly growing municipality, that some extended reference to it may be useful.

The organization of the Street-Cleaning Department, as a separate branch of administration in New York City, dates from the year 1881, up to which time the collection and disposal of wastes was carried on under the direction of the Department of Police. The new organization was the outcome of much agitation on the part of the public; physicians and political reform associations taking an active part in the crusade.

For ten years after its formation the Department did little to justify its existence. On the contrary, it became such an object of dissatisfaction that, in 1891, it was determined to appoint an Advisory Commission to inquire into the defects of the organization and to recommend measures of improvement.

The Commission was named by Mayor Hugh J. Grant, and consisted of five citizens, among whom were two business men, a lawyer, a sanitary expert and an engineer, the last being a member of this Society.

The report of Mayor Grant's Commission marked an epoch in the history of the Street-Cleaning Department of New York City. It is, moreover, so remarkable a document, from the clear and exact way in which the faults and needs of street-cleaning departments in general are defined, that a summary of its findings is here given:

In the first place it was declared that the department was not efficiently managed, as judged by standards of management of well-established corporations engaged in large enterprises.

One source of difficulty lay in the methods of employing labor. The laborers themselves were inefficient, and owed their positions to political influence.

The plant of the Department was poorly located.

The plant was insufficient.

There was a lack of proper organization and disposition of forces.

The manner of disposing of refuse was not satisfactory.

The law under which the Street-Cleaning Department was conducted was adequate, provided it was efficiently administered by a Commissioner who had the cordial co-operation of the Mayor, Police Justices, Department of Health, Commissioner of Public Works, and Board of Estimate and Apportionment.

The annual appropriation was insufficient.

The police should help to keep the streets clean.

There should be rules for the employment of men.

Mr. Soper.

It was observed that the management of the Street-Cleaning Department required the same kind of ability as the management of a transportation company, or other large corporation employing a considerable number of men.

The report of Mayor Grant's Commission, one of the most forcible and lucid papers on this topic which the speaker has ever read, is the foundation upon which the present organization of the Street-Cleaning Department is based. The practical effect which the report had was a reorganization of the Department by legislative enactment in 1892.

Unfortunately, the opportunities thus opened for developing an efficient system of street cleaning were not at first realized. The first thing done in accordance with the recommendations was to increase the appropriations. Then progress ceased. The Department promised to remain as it had always been, an organization in which political influence was carefully and continually fostered.

By the time Mayor Strong's reform administration of 1895 came into power it was apparent that there was need of a strong head to develop the possibilities of improvement contemplated in the legislative act of reorganization. It is now a subject of universal satisfaction that such a head was found by Mayor Strong when, in 1895, he appointed the late Colonel George E. Waring, Jr., Commissioner of Street Cleaning. Whatever may be said of Waring's career, as an engineer or sanitary reformer, it must be admitted that in the three years during which he held office as Commissioner of Street Cleaning he made comparatively few mistakes and reached the greatest success, in raising the standard of usefulness of his Department, that New York City has ever known.

At the same time, it is not to be denied that circumstances favored Waring. A large part of his success was achieved on lines laid down in the report of Mayor Grant's Commission of 1891. Waring also had the advantage of a report of a Legislative Committee of investigation and advice appointed by Mayor Gilroy in 1894. The report of Mayor Gilroy's Committee, dated November, 1894, recommends that:

First.—Dumping city refuse in the harbor or its tributary waters should be absolutely prohibited.

Second.—The ordinances requiring householders to keep separate the garbage, or kitchen refuse, from ashes and other house refuse should be rigidly enforced.

Third.—All house refuse should be collected in galvanized iron vessels with tight-fitting metal covers, of such size that, when full, they can be handled by one man.

Fourth.—Daily collections of garbage should be made by the City and delivered at dumping wharves into temporary storage, or self-

Mr. Soper. propelled boats of some approved type to be furnished by the party having the contract with the City for the final disposition of the garbage.

Fifth.—The garbage should be disposed of by a reduction process producing fertilizer and commercial grease; and the City should invite competition by the various companies controlling such systems, in order that the greatest benefit to the City may result.

Sixth.—A separate collection should be made of the remainder of the refuse of the City " not otherwise provided for," which should be used for filling Riker's Island, or elsewhere; and, for transportation of this material, a sufficient number of self-propelled boats of approved type should be constructed and owned by the City. It should be provided, however, that whenever the whole, or any considerable portion, of the street sweepings can be disposed of by contract or sale for fertilizing purposes, at a price greater to the City than the value for filling, then such disposition should undoubtedly be made of them.

A careful reading of the foregoing recommendations will reveal on the one hand some excellent advice and on the other some stipulations which had the effect of committing the City to a particular process of garbage destruction and the plan of disposing of garbage by contract with a private company.

Some prominent reforms introduced by Waring were: Improved methods of administration; insistence that the laws and ordinances relating to cleanliness and order in the streets be enforced; and improvements in methods of collecting and disposing of the wastes. A large part of Waring's success, as the head of the Street-Cleaning Department, was due to his remarkable power of instilling a spirit of industry among his men. It has been well said that he found the force of sweepers and drivers a laughing-stock and left them a body of honored workmen.

It is well known that, after reorganizing his working force, Waring's ambition was to devise means for the economical, if not profitable, final disposition of the City's refuse. Up to Waring's time, the ashes, paper, garbage, and other refuse of the city had been collected and carried in a mixed condition to points along the water front where it was picked over by Italians, who had the privilege of extracting bones, bottles, rags, metals, and other salable matter. This privilege was purchased from the City annually, and in 1894 amounted to $140 000. The residue left over after the picking was taken by scows and dumped at sea or used to fill in low lands in the neighborhood of the City.

Under Waring, the City wastes were separated, as is the custom to-day, into three classes before collection; notably, garbage, ashes and

Mr. Soper.

paper. Experimental studies were made of the value of these different kinds of refuse. Garbage was also collected from other cities, and the value of its grease and other constituents carefully determined. According to estimates, made at the time of these studies, the average quality of garbage produced in New York City was worth $2.47 per ton.

A practical plant for the separation of the utilizable ingredients of refuse, other than garbage, was erected and operated for many months. The sale of the bottles, metals, rags, paper, and other useful materials, thus collected from 31 300 tons of refuse, netted the City $3 680. A considerable amount of useful steam-power was also generated at the same time.

It is a lasting source of regret that Waring's term of office was too short to enable him to complete the development of a plant whereby all of the wastes of the City could be disposed of profitably, or at least inoffensively. Just as his investigations were pointing to positive and permanent reforms his term ceased.

At the end of Waring's administration the efficiency of the Department immediately fell. The Commissioners who followed seem not to have been suited by talents or experience to conduct the Department on the plane of efficiency which Waring had initiated. Negligence, extravagance—some have said, corrupt practices—crept into the affairs of the Department. A single illustration will suffice to convey the speaker's meaning. The following extract is taken from page 24 of the Annual Report of the Department of Street Cleaning for 1900:

> "In September, the New York Sanitary Utilization Company complained that it was not receiving all the garbage to which it was entitled by the terms of its contract with the City, on account of faulty separation, and claimed that the scow-trimming contractor was culling bones and grease for sale to which they, the New York S. U. Co., were entitled, and to which the scow-trimming contractor, by the terms of his contract with the City, expressly denied any claim or right. The matter was finally compromised by the Department paying to the scow-trimming contractor sixty cents per barrel for bones and one and three-quarters cents per pound for grease collected from the ashes, which was turned over to the Sanitary Company. This arrangement resulted in a continual increase week by week in the quantity of this material collected from the ashes and street sweepings, so that for the last week in December the Department's payments to the scow-trimming contractor amounted to $2 127.41."

The charter of Greater New York, which went into effect in 1898, added much to the responsibility of the Street-Cleaning Commissioner, and complicated the unsolved problems of his imperfectly developed department. The plant of the Department should have been increased and the organization properly expanded to meet the requirements of the Greater City, but it is clear that no such logical development was contemplated.

Mr. Soper. The unsatisfactory condition of the streets of New York City at the beginning of the present administration is well known. Many of the innovations and improvements introduced under Waring were discontinued and forgotten. Much of the plant was out of order and some of it out of service. Two self-propelled refuse barges were laid up, apparently for no other reason than that they were too economical. Horses were out of condition, overworked, poorly cared for. The dumps and docks were in a disgracefully insanitary condition. The force of laborers was demoralized. The streets were filthy. The rules of the Department, and especially the City ordinances, were shamefully neglected. The policy of entering into contracts with private parties had been extended. The method of letting contracts was open to severest criticism. A contract for the disposal of the garbage of Manhattan had to be let at an exorbitant figure because bids were not called for until too late to secure profitable competition.

Were it not that commerce, convenience and health demand that the collection and disposal of the City wastes be carried on in an efficient manner, the great cost of the Department of Street Cleaning would furnish a sufficient reason why its work should be well done.

The City Budget for 1903 calls for an expenditure of nearly $5 400 000 to pay the running expenses of the Department of Street Cleaning. No other Department of the City Government, except the Departments of Police and Education, spend so much money. The annual cost of the Department of Street Cleaning exceeds the cost of many other Departments combined.

It may be profitable to consider for a moment the chief items of expense, as shown by the Annual Reports of the Commissioners of Street Cleaning:

First: Sweeping.—By this is meant the collection of dirt, etc., from the pavement. This item, in the year 1901, for Manhattan and the Bronx, amounted to $1 402 056.82.

Second: Cartage.—This includes the hauling of refuse material, such as garbage, ashes, paper, and other like refuse. Carting, in 1901, in Manhattan and the Bronx, amounted to $990 577.71.

Third: Final Disposition.—This means the reduction of garbage by contract, dumping of ashes and other dry refuse to fill land, and sea dumping. In 1901, final disposition, for Manhattan and the Bronx, cost $733 602.01.

Fourth: The Removal of Snow and Ice from the Streets of Heaviest Traffic.—This item, in 1901, is said to have been about $600 000.

Fifth: Administration.—Administration cost $223 456.62, in Manhattan and the Bronx, in 1901.

Sixth: Rents and Contingencies.—For Manhattan and the Bronx, this item amounted to $121 490.07 in the year 1901.

The total sum represented by the foregoing items is $4 071 183.23. Mr. Soper.

From the reports of Mayor Grant's Commission, and the Commissioner of Street Cleaning for 1900, the expenses appear to have increased out of all proportion to the quantities of refuse removed. The figures are as follows:

Year.	Appropriation.	Loads of Refuse.
1882	$1 010 000	1 116 360
1890	1 280 525	1 702 102
1900	5 584 100	2 602 120

But the cost of the Street-Cleaning Department, as shown by the official reports, does not represent the total cost to the citizens for removing and disposing of the City's refuse. Other items of expense are the removal of dead animals from the streets, the removal of manure from stables, the removal of market refuse, the removal of cellar dirt, and the sprinkling of streets.

The largest extra is for private carting. An immense number of property holders employ private scavengers. Hotels, office buildings, apartment houses, restaurants, manufacturing establishments, retail dry goods shops, and many residences are compelled to remove their wastes at their own expense. Recently, even the privilege of the City dumps has been denied to cartmen, and it is said that in some cases refuse has had to be hauled several miles and carried across ferries for disposal.

The total expense of the extra scavenging work made necessary by the inability of the Street-Cleaning Department to collect and dispose of our municipal wastes in a satisfactory manner is very large. In 1891 the sum paid for the private collection of refuse was estimated to be between $150 000 and $175 000. It is now very much larger. The quantity of refuse of various kinds dumped at City wharves by private carts has been more than 30% of the total quantity collected by the Department of Street Cleaning. In addition, more than 100 tons of swill per day are carried out of town to be converted into soap, or fed to cattle and swine.

In reply to a request from the Board of Aldermen, for a specification or draft of the organization necessary to handle the output of refuse of the large office buildings, stores and places of business which now employ private scavengers, the Street-Cleaning Commissioner said, a few days ago, that he would require 500 additional horses, 500 carts, 500 drivers, 50 hostlers, three stable foremen, three assistant stable foremen, nine stable clerks, twenty stablemen, proper stabling for the horses, and spaces for the carts, together with such equipments as harness, blankets, buckets, etc., and proper water-front facilities for the handling of this material. The total number of carts and trucks now under the Commissioner, in Manhattan and the Bronx, Mr. Soper. 744. By making his request for 500 more carts, the Commissioner tacitly admitted that 40% of the work of removing refuse in New York is now done by means outside of his Department and beyond his control.

The private collection of refuse is objectionable, from every point of view. It leads to insanitary practices, and is an item of expense and annoyance from which the taxpayers of the City should be free. The cost of private collection is not equitably distributed, but is often heaviest upon those who pay the largest taxes. But there is no use in emphasizing the evils and extravagances of the present situation. If the force, plant and organization of the Department of Street Cleaning were adequate to the needs of the City there would be no excuse for them.

If the foregoing remarks carry any clear idea, it must be that the work of collecting and disposing of the wastes of the metropolis is badly done. Such efficiency as exists is due largely to the energy of the present Commissioner and the effects of the two notable epochs, in the history of the Department, to which reference has been made. The first of these epochs was the investigation, report and reorganization due to Mayor Grant's Commission. To this may be added the investigation and the improvements suggested by the Committee of Advice appointed by Mayor Gilroy. The second epoch was marked by the tenure of office of Colonel Waring.

In the history of the Department, few, if any, important reforms or developments have been made which were not the result of seeking outside investigation and advice. Is it not time that the disposition of the City's wastes be again made the subject of an exhaustive inquiry?

At the present moment the City is deplorably dirty. Business men and property holders are complaining that their refuse is not removed, and an immense sum of money is being spent for the collection and removal of wastes which, upon theoretical considerations, are valuable. The Street-Cleaning Department is struggling under the disadvantages of an imcomplete and outgrown equipment. It may seem like strong language, but it is not beyond the facts, to say that the system of cleaning the streets of the metropolis, if followed by a private corporation, would lead to bankruptcy.

The speaker intends no unfriendly criticism of Dr. Woodbury, our able Street-Cleaning Commissioner, in stating that the length of his term and the power of his office are not sufficient to enable him to correct, single-handed, the mistakes of the four years of mal-administration which preceded him, and place the Department on the efficient footing which the citizens have a right to expect. To meet the changed conditions due to the recent phenomenal growth of New York City, the Department needs to be developed, expanded and made as efficient as it was in Waring's time.

Mr. Soper.

The speaker sees only one way by which these ends may be accomplished, and that is through the work of a Commission of Investigation and Advice, such as was appointed by Mayor Grant.

In the speaker's view, the most important specific problem pressing for solution is: How shall the City's wastes be finally disposed of? This is the keystone of the great question as to the best means of organizing and equipping the Department of Street Cleaning.

Second.—Another query is: Is it well for the City to enter into contracts with private individuals for horses and carts to collect the refuse, for barges to remove it to a distance and for reduction works to dispose of it?

Third.—One more question is: How can the ordinances relating to the careless littering of streets and the separation of refuse be enforced?

Fourth.—Finally: In what ways and to what extent should the plant of the Department be increased?

Without desiring to amplify this last interrogation unduly, or to presume to possess the knowledge required to answer it, the speaker would state that it is believed, by those who have taken an intelligent interest in the Department, that more and better dumps are needed; more and better scows are needed; more and better carts and horses and stables and stations are needed; and refuse destructors or garbage crematories, built in accordance with the best known practices, are needed. In addition, very possibly, street-sweeping machines and snow-melting machines are needed.

It should not be an open question whether mechanical devices cannot, to some extent at least, replace the hand labor which is now the chief item of expense in cleaning the streets.

The present moment is propitious for an investigation. The existing administration is pledged to municipal reforms, and has executed or planned several admirable lines of improvement. The present Street-Cleaning Commissioner has demonstrated, by a year's administration of his office, that he has the capacity, energy and determination to put in force such measures of relief and permanent improvement as may be placed within his reach. The work of the Commission which the speaker suggests would greatly facilitate his efforts to bring the plant and organization of the Department to a high state of efficiency.

It is a pleasure to say that the plan of appointing a Commission has received Dr. Woodbury's endorsement, and that Dr. Lederle, President of the Board of Health, has given it his approval.

Mr. Horton.

Theodore Horton, Assoc. M. Am. Soc. C. E.—The Trenton garbage plant was a source of serious trouble during last summer (at a time, in general, when such plants give evidence of any defects in design or management), and a consulting engineer was called upon to investigate

Mr. Horton. and make a report to the City in regard to it. He was asked, first, to determine the nature and extent of the trouble, and, secondly, to make such recommendations as might be needed to relieve the situation.

The details of the work, in a great measure, devolved upon the speaker, and he will describe briefly what occurred during his visit.

The plant, which, unfortunately, was located in the midst of a thickly settled district, consisted of two Davis destructors connected with a stack 120 ft. high. Each furnace consisted of a combustion chamber; a drying chamber, below which was located an evaporating pan; secondary fire grates; a flue of somewhat contracted area leading to the chimney; and a set of screens to intercept dust particles.

The speaker spent the first day in familiarizing himself with the construction and operation of the plant, and in getting under headway a systematic record of the various features which would lead to a solution of the trouble. These consisted of a record of weights of garbage consumed, coal burned, and ashes; the times of delivery of garbage, charging of furnaces, firing, cleaning grates, operating dampers, and such other observations as might throw light upon the causes of the trouble.

While these records were being kept by the various employees of the plant, other observations, of a special nature, were carried on under the speaker's personal supervision. Thus, he made several analyses of the garbage, which in this particular case was a very important element, due to the fact that it was that known as kitchen garbage, or swill, and was free from ashes. At that season of the year, it was practically saturated. These analyses were simple, and consisted of merely assorting samples, of about ⅛ ton each, into various parts and weighing them. The garbage was found to consist of 84% animal and vegetable matter, 12% paper, 3% rags, carpets, etc., and 1% boxes, barrels and other rubbish; 80% of the whole being water.

Other observations were made to determine the extent of the trouble arising from the dust particles which, emanating from the stack, were causes of much annoyance to the residents of the neighborhood, and of alleged fires in the immediate vicinity of the crematory.

The observations made during the daytime were simple in nature, but served at least to give a tangible idea of the actual conditions. They consisted of observing, at various distances from the crematory, and in the line of smoke from the stack, the number of particles passing a vertical plane in a given time. The distances selected were ¼, ⅓ and ½ mile, and the interval of time 15 minutes. The particles were from ⅛ to 1 in. equivalent diameter, and of course were plainly visible.

In order to present this source of trouble in a still different light, other observations were made by selecting places in the open fields, at various distances from the crematory, and counting the number of particles deposited on an area of 50 sq. ft. During both the foregoing sets of observations, which covered a period of about 3 hours, the wind had been blowing steadily from the same quarter, so that, considered as a whole, the record really had a comparative value, notwithstanding its approximate nature.

In order to get some idea of the danger caused by these dust particles as regards the alleged fires in the vicinity, observations were made upon the glowing embers emitted from the stack at night. Thus, it was observed that:

First.—No embers were seen in a state of actual flaming.

Second.—Glowing embers were emitted principally at times when the furnace doors were open for firing, raking or cleaning.

Third.—During these times it was estimated that, on an average, 50 to 100 sparks were emitted per minute. Of these, it was estimated that 50% did not travel, in a glowing state, further than 25 ft. from the top of the stack; 90% not more than 50 ft.; 95% not more than 75 ft.; 99% not more than 100 ft. and an occasional spark from 150 to 200 ft.

In studying the question of internal combustion in the furnaces, other observations were made, to supplement the general record kept by the employees. These, however, were mostly of a superficial nature and hardly admitted of any refinement, except, perhaps, a determination of the temperature of the flue gases, and even this was somewhat approximate. The speaker had suspected that the temperatures were very low, and at first had tried 500° mercurial thermometers, but, after breaking two of these, and not being able to obtain a pyrometer, he resorted to the somewhat crude method of exposing in the flues metals having different melting points. By a system of elimination, these experiments indicated a temperature of between 800 and 900°, which was sufficiently close for the desired purpose.

At the end of the week's run, the foregoing records were tabulated and studied, and the following is a summary of the results:

RESULTS OF OPERATION OF GARBAGE CREMATORY AT TRENTON, N. J., FOR THE WEEK OF AUGUST 4TH–9TH, INCLUSIVE, 1902.

Total garbage burned	188.0	tons.
Garbage burned per day	31.3	"
Coal used on main fires	10.7	"
Coal used on auxiliary fires (estimated)	3.0	"
Total coal used	13.7	"
Coal used per day	2.3	"
Garbage burned per ton of coal	13.8	"
Approximate average time of burning each day	14.0	hours.

Mr. Horton.

Equivalent number of days of 24 hours	3.5 days.
Equivalent garbage burned per square foot of grate area, per day of 24 hours	1 080 lbs.
Equivalent amount of garbage burned per cell of 25 sq. ft., per day of 24 hours	13.5 tons.
Estimated total amount of clinkers from garbage and coal grates	14.0 "
Estimated amount of ashes from below grates	3.0 "
Estimated total amount of ashes and clinkers	17.0 "
Percentage of ashes and clinkers to garbage burned	9.1 per cent.
Range of temperature of flue gases in stack	600°-1 000° Fahr.
Percentage of moisture in garbage	81.0 per cent.
Corresponding water evaporated daily in furnaces	25.5 tons.
Quantity of coal required per day to evaporate this water, on a basis of 10 lbs. of water per pound of coal	2.5 "

A discussion of all the questions involved in the investigation of this plant has been embodied in the report of the consulting engineer, and as this has already been published elsewhere in full, the speaker will give merely a brief abstract of the conclusions reached and the recommendations made to the City, as follows:

"1.—Notwithstanding the existing defects and the criticisms which it has been necessary to make, the Trenton furnaces belong to the better class of such plants in our country, and the troubles and nuisances with which you are now contending, are also more or less common elsewhere.

"2.—The collection in well-constructed metal carts, such as you have, and also the frequency of your collections, are quite satisfactory. It may be suggested, however, that provisions for thorough cleaning of the carts after dumping would be a still further improvement.

"3.—To obviate the nuisances of dust escaping at the stack, either from well-burned or unburned garbage, it is necessary, after securing perfect combustion, to introduce a dust-settling chamber of proper size between the furnaces and the stack, containing baffles and properly placed inlets and outlets. The screens now in the chimney, although useful as a safeguard against accidental emissions of light but large matter, are insufficient to retain all of the matter now escaping from the furnaces.

"4.—To reduce further the possibility of unburned particles escaping through the stack, it is important to place dampers in the flues leading from each furnace, as well as in the chimney, so as to afford control of the drafts at all points where and when it is needed.

"5.—The garbage now delivered, when properly drained and carefully burned in a well-designed furnace, is readily combustible, and should not require the addition of as much coal as now used; and at some seasons, except to start fires, and, otherwise, on rare occasions, perhaps no coal may be required.

Mr. Horton.

"6.—We find that the furnaces are not sufficient in size to effect a complete destruction of the material during the hours of the day when the crematory is operated. Continuous firing for 24 hours can relieve this sufficiently. To this end it would be necessary to store the material for a part of the day, and this could not be objectionable in any way.

"7.—To secure a complete combustion of the garbage, more economically than at present, the design of the furnaces should be somewhat altered. The horizontal grates are not the most suitable for the material, which must first be dried, and then with difficulty pulled from one position to another for burning. A sloping grate for burning, and a sloping floor for the drying chamber, from which the material can be gradually and almost automatically moved from the feed-hole to the hottest portion of the fire, permit of a better utilization of the heat, and reduce the difficulties of stoking.

"These recommendations, supplemented by a systematic attention and skillful practice on the part of the Superintendent and his subordinates, would enable them to operate the crematory so that nuisances from odors and dust would cease."

Mr. Firth.

Elmer W. Firth, Jun. Am. Soc. C. E. (by letter).—The use of public dumping places within the city limits is an important phase of refuse disposal as applied to New York City. In the Borough of Brooklyn, for instance, there are deposited at these places, not only ashes, but the dust and dirt gathered from public and private buildings and conveyances, the soiled sawdust from wooden cuspidors, street sweepings, and much garbage and other refuse. Much of this deposit is subsequently blown about the streets in the vicinity, and the Health Department has received many complaints as to the frightening of horses, and other unpleasant experiences resulting from flying papers, etc., from these dumps.

The transportation of such large, material suggests a greater distribution of dust and dirt through the air in these localities, and, possibly, an increased morbidity or mortality due to this condition. Figuring the average diphtherial death-rate in Brooklyn, by wards, from statistics in the Health Department reports for 1895 and 1896, it was observed that this death-rate was higher in the vicinity of the public dumping grounds than in other sections of the city. The writer hesitates to mention this as more than a coincidence, admitting that the relative number of cases of sickness would be a better basis for comparison. Then, also, it may be said that as these dumping places are generally located in the poorer sections of the city, scanty or inefficient medical service would increase the number of fatal cases in these localities; but against this argument may be placed municipal supervision, quarantine and the free distribution of anti-toxine.

It should be noted that in diphtheria the seat of infection is in the respiratory passages. The bacillus recognized as its cause withstands prolonged drying, and may be carried through air in a virulent condition. While it is not claimed that this specific disease is transmitted

Mr. Firth. directly by the dust blown about, from these deposits of refuse, yet a predisposition to it may result from constantly inhaling such impure air.

Even if the deposition of such refuse is not proved to be accountable directly for much of the suffering in these places, it at least maintains an unsanitary condition in the very communities where the death-rate is highest and in the midst of classes least capable of avoiding infection or of curing disease.

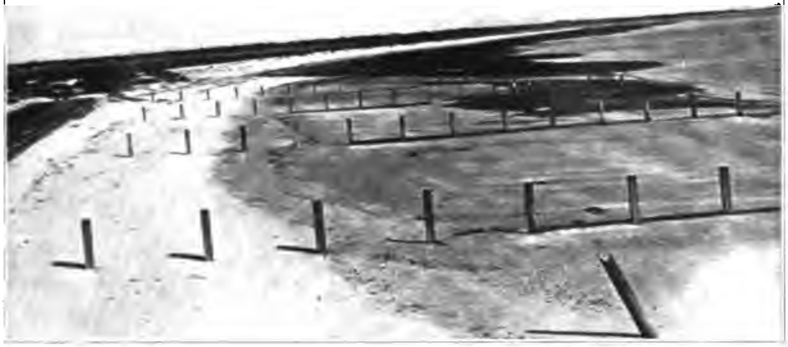

FIG. 1.—BEACH, WITH GROYNES IN POSITION, JUNE 27TH, 1902.

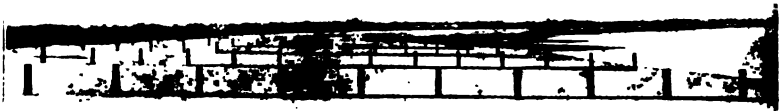

FIG 2.—BEACH, ON DECEMBER 20TH, 1902.

1900

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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THE PROTECTION AND IMPROVEMENT OF FORESHORES BY THE UTILIZATION OF TIDAL AND WAVE ACTION.

Discussion.*

By E. Burslem Thomson, Assoc. M. Am. Soc. C. E.

† E. Burslem Thomson, Assoc. M. Am. Soc. C. E. (by letter).—Two photographs of the groynes mentioned in the writer's previous discussion‡ are shown in Plate XIII. Fig. 1 was taken on June 27th, 1902, when the first tier of planks and some few of the second tier had been set in place. These show the irregularities of the beach, as well as the dark patches of marsh mud. Fig. 2 was taken on December 20th, 1902, shortly after the third tier, and in some parts the fourth tier, had been placed. The improvement in the slope and the disappearance of the mud patches, as well as the general rise in elevation, are indicated clearly in these views. Mr. Thomson.

Beyond the region of action of the groynes the mud flats still exist. It is to be noted that the first four posts from the face of the timber dam are not brought into use, the groynes commencing at the fifth post.

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* Continued from November, 1902, *Proceedings*. See August, 1902, *Proceedings*, for paper on this subject by R. G. Allanson-Winn, M. Inst. C. E., I.

† This part of Mr. Thomson's discussion was contributed subsequently by him.

‡ *Proceedings*, Am. Soc. C. E., November, 1902, p. 810.

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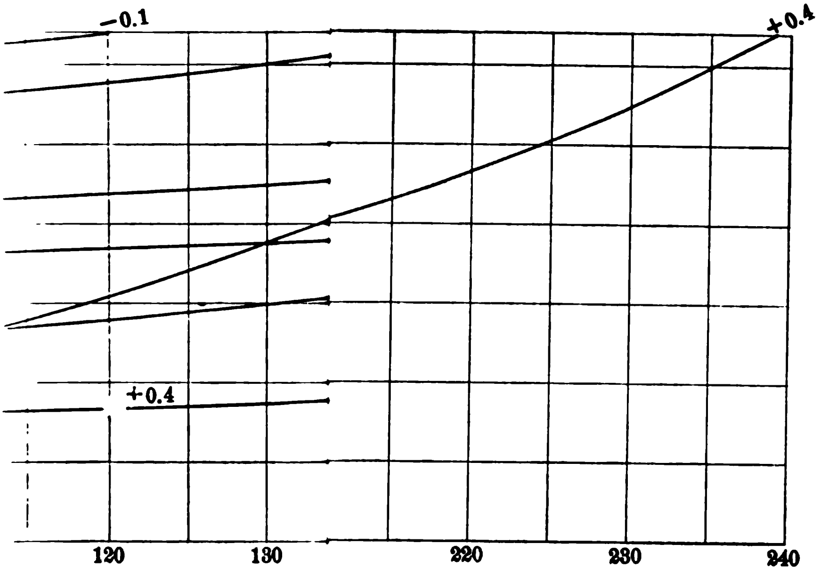
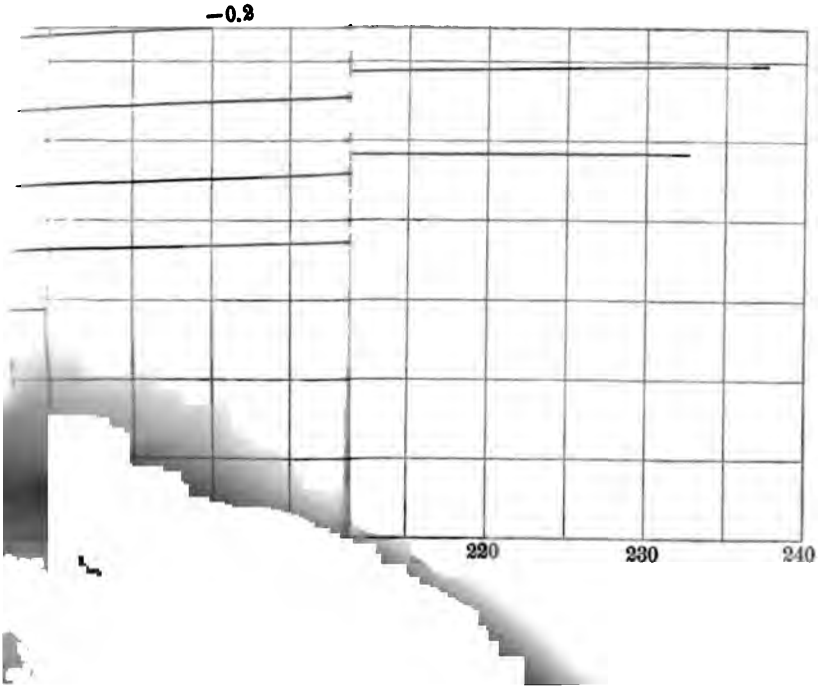
PLATE XIV.
PAPERS, AM. SOC. C. E.
JANUARY, 1908.
PURDON ON VIRTUAL GRADES.

AD AND TRAIN

ED OF 12 MILES PER





Mr. Purdon.

established, so that the momentum can be calculated with considerable accuracy. On a new road, all these points will come up later, and if momentum grades were established on a new road, the introduction of a water tank or a new station, or some other reason, might destroy all calculations.

The writer does not consider the author's diagrams as the most convenient for the purpose, and submits herewith two diagrams, Plate XIV, such as he uses. These take no account of the speed of the train, but use the velocity head, which, of course, is interchangeable with the speed. These particular diagrams are calculated for a train that can maintain a speed of 12 miles per hour on a rising grade of 0.5 per cent. The accelerating grades start with a velocity head of 0.88, equal to 5 miles per hour, and, after a stop at a station, the distance required to gain this velocity is taken as the starting point on the accelerating grade.

The upper diagram shows the retarding grades, and stops at 3.55, equal to a speed of 12 miles per hour, so that by taking any velocity head required by the upper diagram the distance on any adverse grade which would be run by a train before the speed would fall to 12 miles per hour can be ascertained. The diagrams are calculated in substantially the same manner as those by Mr. Dennis,* but in making the calculations the rating diagram of the Southern Pacific Railroad was used, which gives varying train resistance on account of speed from 4.8 lbs. per ton at ten miles per hour to 20½ lbs. per ton at 46 miles per hour. It is noticed that this does not agree with Mr. Dennis' paper, as he states that the train resistance is nearly the same for speeds between 7 and 35 miles per hour. At stations, of course, the grade should be somewhat lighter for a short distance on each side, to enable a train with a maximum load to start; and, in ascertaining the momentum, it should be calculated as if the train stopped at each station.

Mr. Hebblethwaite.

F. H. Hebblethwaite, Assoc. M. Inst. C. E.—In the year 1900 the speaker was engaged at the Naval Yard Extension Works, in Hong Kong, in laying out a yard for the manufacture of concrete blocks. The concrete was machine-mixed at one end of the yard, run down grade on trestles in cars of 18-in. gauge, and dumped into moulds, the empty cars being pushed back by hand. A loaded car weighed 4 000 lbs., the empty car 500 lbs.

The speaker would like to ask the author how he would determine the grade down which the loaded cars could be pushed with exactly the same expenditure of power as would be requisite to push the empty cars up; in fine, the grade to be laid out so that a man could as easily push an empty car up as a loaded car down. There must be such a grade. How can it be determined ?

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* In a paper published in *Engineering News*, November 22d, 1900.

Mr. Raymond.

WILLIAM G. RAYMOND, M. Am. Soc. C. E. (by letter).—The writer supposes that the late A. M. Wellington, M. Am. Soc. C. E., was the first railroad engineer to discuss at all adequately the problem of momentum or velocity grades, and, for a number of years after the appearance of his discussion, comparatively little attention was paid to the subject; but, for the past five or ten years, railroad engineers all over the country have been somewhat carefully studying and experimenting with such grades, and there have appeared in print, in the technical press and society proceedings, a very considerable number of discussions, both purely theoretical and as the result of extended experiments.

But while we engineers are figuring theoretically the gains to be secured by the consideration of momentum or velocity grades, and while the western roads have, in many instances, laid out such grades and operated them with apparent success and economy, we are met by the manager of the busy eastern road with the statement that on his road he does not dare to start out a train the engine of which is loaded with a load greater than that with which it can start from a state of rest on the steepest *de facto* grade over which it is to pass.

The writer himself, from time to time, has taken part in discussions of momentum grades, and has devised formulas for the lengths of such grades for given locomotives and resistances, and has discussed at some length the most economic speed of freight trains and the principles which should govern in the design of locomotives for operation on divisions of varying characteristics; and while he thoroughly believes that considerable economy may result from a consideration of momentum or velocity grades, in the cost of original construction, in the revision of gradients on existing roads, and in the designs of motive power and its operation; nevertheless, he can well understand that on a busy road the cost of a single unexpected stop, due to too close figuring on the possibility of momentum grades, may equal or exceed the gain resulting from such considerations for a considerable period of time during which there is no such accidental stop.

The writer believes that the subject is one of considerable importance because of the possible economies involved, and thinks that a fairly complete knowledge of the prevailing practice in this matter would be of very considerable value and interest, and, therefore, he suggests the advisability of securing the opinions of operating managers on this subject, and a statement of any experiences that such managers may have had in the consideration of momentum or velocity grades. He thinks that it might be wise to invite formally such expressions from officers responsible for the operation of both eastern and western railroads. These officers may include chiefs of motive power, general superintendents, general managers and chief engineers, according to the duties and responsibilities assigned to these different officers on the different roads.

A. C. DENNIS, M. Am. Soc. C. E. (by letter).—The writer fully agrees with the conclusions in the first part of Mr. Fulton's discussion on virtual grades, and was equally skeptical in regard to the approximate constancy of train resistance until convinced by a long series of experiments. He knows from experiment that a train of about 2 100 tons, with 20% empties, picked up speed from 29.5 to 30 miles per hour, with the locomotive shut off, in running 2.5 miles on a 0.26% grade. The writer suspects that a long train of all loads would exceed 40 miles per hour on a 0.3% grade with the locomotive shut off, provided the train had been running at high speed, but lacks sufficient information regarding resistances at such speed to be able to state definitely. A train of all empties will lose speed in coasting, even on a 0.4% grade, whatever the speed when starting to coast. It is impracticable to compare the resistance of two trains without knowing the proportion of tare weight, or reducing all actual tonnage to rating tonnage. Mr. Dennis.

The "boiler momentum," to which Mr. Randolph refers, will probably explain the difference between Mr. Fulton's speed and distance diagram and that of the writer.

The writer's locomotive tractive power curve for high speeds is much above the capacity of the locomotive to produce indefinitely, but not above that produced temporarily in making runs at grades. The available stored energy is roughly equivalent to 2 lbs. per ton of train or to 0.1% of grade.

If Mr. Fulton did not consider the extra temporary boiler power, but calculated his locomotive power as strictly limited by the steam-generating capacity, his diagram should show the same results, for any rate of grade, as the writer's does for the next tenth higher. Comparing Mr. Fulton's diagram with the next tenth higher corresponding grade on the writer's diagram shows a very gratifying correspondence until a mile is covered, or low speed reached, where the two diagrams are practically the same, as the boiler momentum has then ceased to influence the writer's diagram. As before noted, after passing the first mile, on a grade where the locomotive is worked hard at a speed exceeding ten miles per hour, the grade line on the writer's diagram does not hold, but the true results are approximated by following from this point parallel to the curve of the next tenth lower grade rate. The boiler momentum, though not capable of being calculated exactly, should be considered, and has been rather undervalued by the writer, as trains require more speed and hold it better when running for momentum grade than is indicated by the writer's diagram, except for long hills, where the diagram falls short, as noted.

The problem of momentum grades contains so many personal, mechanical, and other variables, that an approximate solution only is possible. A close approximation only is necessary, as trains are not

Mr. Dennis. loaded ordinarily to the last ton possible, because they cannot make the required time; so a little too much momentum grade introduced will not cause stalling, and if not as much as was possible were used, some returns are obtained, for the extra construction expense, in the running time saved.

The custom, on eastern railways, of sticking to an assumed maximum grade rate, regardless of cost, stations or speed possibilities, gives a line of higher first cost and generally of a lower operating value, because of the high ruling grade at stations. Momentum grades, based on the assumption that the locomotive exerts the same tractive power at all speeds, will lead to serious error. Somewhere between these extremes is the proper use of momentum, where the greatest liberty is taken with the grade rate to make it fit the ground, limited only by the ability to join with proper vertical curves and the capacity of the locomotive plus momentum to make the required speed. Engineers who look on the percentage of rate of grade as the end and object of a railway have mistaken the measure for the thing itself. A grade should be limited, not to a maximum rate, but to the locomotive power, and the momentum then made to fit the ground. The mere rate of grade is irrelevant and often misleading.

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PAPERS AND DISCUSSIONS.

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AN ALTERNATIVE LINE FOR THE NICARAGUA CANAL; AND A PROPOSED NEW METHOD OF DAM CONSTRUCTION.

Discussion.*

By J. Francis Le Baron, M. Am. Soc. C. E.

J. **Francis Le Baron**, M. Am. Soc. C. E. (by letter).—The writer did not expect that the members of the Canal Commission would be swift to approve any change of route of the canal that they had already located after such careful examinations, but he recognizes fully the fact, illustrated so clearly by Mr. Noble, that the Isthmus is a country of surprises, and he felt that possibly a surprise might be in store on the south side of the San Juan, if a survey should be made there. Most of those who have taken part in the discussion have fallen into the error of supposing that the writer advocated this route as a finality, whereas he was careful to state in the paper that he believed the facts warranted a careful survey and examination, and that is as far as he felt warranted in going. **Mr. Le Baron.**

In replying to the discussion, the writer wishes first to mention the map, Plate XXXVIII.† As Mr. Noble surmised, the foundation of this map is the one published in the report of the Nicaragua Canal Commission, which is a reproduction, with additions and corrections, of the map published in the Lull Report of 1872-73. To the Commission's map the writer has added the topography developed by the special surveys and reconnoissances of the Nicaragua Canal Commission and

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* Continued from December, 1902, *Proceedings*. See October, 1902, *Proceedings*, for paper on this subject by J. Francis Le Baron, M. Am. Soc. C. E.

† *Proceedings*, Am. Soc. C. E., for October, 1902.

Mr. Le Baron. the Nicaragua Canal Board, all of which are published in their respective reports, and, consequently, are official. There is no other topography on the map; therefore, if "only visible to the eye of faith," their correction is due from Mr. Noble and his associates and engineers.

The topography at the mouth of the Colorado is from the survey of Mr. P. C. F. West, Assistant, United States Coast Survey. The writer was very careful to make use of only actual surveys from official sources. In relation to this subject it may be stated that some of the maps of Nicaragua and Costa Rica show a cut-off, from the Serapiqui River direct to the sea, called the Sucio River. In case this cut-off exists, the whole volume of the Serapiqui, as well as that of the Tiger and Negro Creeks, could probably be turned through it and discharged ten or a dozen miles southeast of the canal, thus greatly simplifying matters. The writer did not allude to this in the paper, because the correctness of the maps had not been confirmed by actual survey, to his knowledge; but it emphasizes the desirability of a survey and examination on the southern side of the river.

The writer admits that the crossing of the Serapiqui is one of the most formidable engineering features of a line south of the river, but he does not believe it to be beyond the pale of engineering skill at the present day, in view of the experience on the Manchester Canal, and others. He examined the river for some distance above its mouth, and found it to be a deep-flowing stream, between steep banks, with a uniform and moderate velocity, carrying a dark-colored water, which shows that it runs through or drains large swamps, and is entirely unlike the San Carlos, which is very rapid and full of sandbars. In fact, the Serapiqui, in the lower part of its course, flows for a long distance through swamps and alluvial plains, whereas the San Carlos issues almost directly from the mountains. The upper courses of the two rivers are probably much alike. In its ordinary stages the Serapiqui is not a sand bearer in the lower part of its course, where it joins the San Juan. This is shown by there being no sand bank or bar at its mouth. The sand that it carries in its upper reaches is all deposited before reaching the San Juan.

The canal line would cross the Serapiqui within a mile of the mouth, and, by placing a movable needle-dam immediately below the crossing, the depth and velocity could be regulated at the time of passage of every vessel. Vessels would lock down or up on each side, as the case might be, which would be governed by the relative elevation of the water in the canal and river. At all events, the locks would be of low lift, not more than half the total rise of the river, or, say, a lift of 6 or 7 ft., and the canal would be taken into the river, not the river into the canal. When ships were passing, the needles in the dam would be closed, forming a slack-water pool of small extent. When the ship had passed and the needles were opened the water would quickly return to its former level, and the resulting scour would preserve the depth of the crossing, no weirs or spillways being necessary. The works required would be two low-lift locks and one needle-dam, with their accompanying guard gates, drift fenders and guide wings, the total cost of which might amount to $3 000 000, which would be paid for by 10 to 20 years of dredging at Greytown Harbor, taking the estimate of Mr. Noble; which dredging would be almost entirely eliminated by using the Colorado mouth. In other words, by an expenditure of $3 000 000 for crossing the Serapiqui, and by locating the harbor at the Colorado mouth and using the forces of Nature to scour out the harbor channel, there would be effected a saving of from $100 000 to $200 000, yearly, forever. **Mr. Le Baron.**

The writer thinks that the charts are at variance with General Hains, as to the Harbor at Colorado. This is a matter of fact, and not opinion. There are open harbors, and there are closed harbors. As shown in the paper, according to the surveys of the United States Coast Survey, a harbor of large extent now exists there for light-draft vessels. The writer has used it—crossing the bar in a vessel of 8 ft. draft. This harbor, as previously stated, consists of Agua Dulce Lagoon, Simon Lagoon and the Colorado River, here about 1 000 ft. wide. At present, for want of more water on the bar, this is a closed harbor to deep-draft vessels; but there is no reasonable doubt that it can be opened by two jetties, as has been done in so many similar places, and, possibly, by a single reversed jetty, on the well-known plans invented by a member of the Commission, and applied successfully elsewhere. Once opened, the current of the river, guided and controlled, will preserve an open channel. Greytown Harbor will require two jetties, and so will the Rio Indio, as admitted by the Canal Commission, and so will any harbor on this coast, Colorado excepted. The latter, possibly, can be built with only one jetty, on account of the strong current and great volume of the river; therefore the position of Professor Haupt is untenable, *viz.*, that the Colorado presents a less favorable condition than Greytown, as the expenditure for jetties would be about the same in both cases.

When making his studies and report on Greytown Harbor, for the Canal Company, the writer was very much surprised to find that the sand movement along the beach, northwest of the Greytown bight, was southeast, or directly into the bight. On the southeast side the movement was in the opposite direction, also into the bight. This was not a temporary drift, but prevailed during the continuance of the easterly winds. The writer's headquarters and residence were on the beach, so that the movement was a matter of daily observation. On account of this sand movement the writer planned the harbor with two converging jetties, placing the easterly jetty 900 ft. east of its present

Mr. Le Baron. position. It was afterward moved west for some reason, when constructed.

The Isthmian Canal Commission in its report admits* the possibility of two jetties being required at Greytown, and also at Rio Indio, which would each be as long, if not longer, than those required at Colorado bar, and with the additional disadvantage that from 500 000 to 1 000 000 cu. yds. of sand would have to be dredged annually to preserve a channel at Greytown, whereas, at the Colorado, it is probable that, with the channel once established, no dredging, or at least only a nominal quantity, would be required, for the reason that at the former place the current is weak and the outflow scanty, whereas at the latter there is a normal discharge of 62 000 cu. ft. per second, and at times nearly double this quantity, and a strong outflowing current to preserve a deep entrance, sufficient, even now, to maintain a channel depth of 30 ft. in the gorge, as is shown by the Coast Survey chart before referred to.

The problem of a canal harbor on the eastern end, then, seems to resolve itself to this: A harbor can be built at Greytown, in the location selected by the Commission, which is a small bight in the coast line, into which is annually being poured from 500 000 to 1 000 000 cu. yds. of sand, as estimated by Messrs. Noble, Haupt and the late Professor Mitchell. This sand movement at this locality has been going on for long geological ages. This is shown unmistakably by the remarkable series of lagoons, some half dozen in number, which have formed back of Greytown at regular intervals, beginning with Silico Lagoon and ending with Greytown Lagoon. The last two—Shephards and Greytown—have been formed in the present or historic age, the latter being completed in 1865, and the former about 200 years before, according to tradition in the locality, which, for confirmation, points to the remains of the old caraval belonging to that redoubtable pirate Shephard, who, in the days of the freebooters, made this lagoon his rendezvous, and from whom it was named. Here he retired after his forays, and, on the last occasion, a storm closed the outlet and the vessel was never able to escape. There it remains to this day, a grim and silent warning of what might happen in the year of grace 2100, in case our dredges should break down or the groynes fail to stop the course of Nature.

It is admitted that a harbor can be built in the place selected at Greytown; but, is it wise to select a point where six harbors have previously been built and filled up? Nothing is impossible in these days of engineering, if plenty of money is furnished. It is admitted that it can probably be kept open for many years by building groynes and by constant dredging, but the groynes must be extended every few years, and the dredging must never stop.

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* Report of the Isthmian Canal Commission, p. 141.

Mr. Le Baron.

The open book of Nature shows conclusively that here the lagoon-building process is still going on, and sand is being brought in from the north and the south. Year after year the sand that will be dredged from the harbor will accumulate around it; the foreshore will keep on increasing and building out, until at last the advancing mole, as was the case with the last harbor, pushes its irresistible way across the floor of the ocean and closes the harbor, and another lagoon is formed, as has been formed six times before. The delta here has been for ages and is still actively building out into the sea. When Greytown Lagoon was formed, this sand mole, advancing from the southeast up the coast, crossed the harbor in 48 ft. of water, and in 15 years completely shut up the once fine port. By building a harbor in the same spot we are inviting the same disaster.

On the other hand, we have the mouth of the Colorado River, a mighty stream, 30 ft. in depth, rolling seaward between banks 1 000 ft. apart, and yearly growing larger on account of the gradual diminution of volume of the Greytown branch, the Lower San Juan. Once inside the bar, here is a harbor capable of accommodating many vessels, as stated in the paper. If this is not a harbor, as General Hains claims, then the Mississippi River from Port Eads to New Orleans is not a harbor. True, the sea breaks on the bar, as General Hains observed; but on what bar does it not break when it has a long reach of deep blue water behind it. The writer. sitting in his office on the beach at Greytown, has seen the spray thrown 20 ft. high, day after day, from the breakers at the site of the Commission's proposed harbor. Breakers in any place certainly do not present very stable equilibrium to a man in a boat; but the fact of their existence being taken to militate against a condition of stable equilibrium of the coastal plain, as General Hains, facetiously, perhaps, infers, is certainly a new postulate in hydrography.

Professor Haupt concludes, from his studies of Greytown Harbor, that "the problem of restoring it is quite practicable and comparatively inexpensive." The datum on which this opinion is based appears to be the fact that a quantity of sand, estimated by himself at 582 000 cu. yds., and by the late Professor Mitchell at 730 000 cu. yds., and which Mr. Noble says may be anywhere from 500 000 to 1 000 000 cu. yds., is annually deposited in the bight where it is proposed to form the harbor; that the advance of the sand mole up the coast was at the rate of 291 ft. per annum, and that from 29 to 31 years, only, would be required to fill or close it. Moreover, he characterizes this movement as "due to the constancy of the prevailing forces"—certainly rather unusual recommendations for a harbor site.

It is true that Professor Mitchell (about 1869) reported that the harbor could be restored. At that time there existed a good, deep

Mr. Le Baron. basin, fully 30 ft. deep, and more in some places; now, the basin will not average 18 ft. deep, and is not more than half the area it was then. At that time the harbor was worth experimenting with; now, it is not. It is not claimed that it cannot be restored now, but it is submitted that it would be unwise to expend any money on it when there exist other locations free from the deteriorating influences that prevail here. It is sure to fill up at the first opportunity, no matter how carefully it is protected by groynes or pumped out by dredges.

The Isthmian Canal Commission, in its report (page 162), states that "the sand movement along the coast seems to be at the maximum at Greytown." It would be interesting to know by what line of reasoning it arrived at a favorable decision to locate a harbor at a point possessing all these disadvantages, and no apparent advantage, except that in its opinion it has "advantages as a working harbor." The writer is forced to agree fully with the Commission in the latter view, considering the amount of sand it estimates must be removed yearly.

The region included between the Colorado and Greytown is a delta, and it is known that deltas are invariably progressive, but, as Professor Haupt very wisely concludes, the movement is cyclic in character in portions of this delta, and this accounts for the erosion at present in the vicinity of the mouth of the Rio Tamo; as Mr. Noble observes, "the action now going on being a straightening of the shore line."

Professor Haupt quotes the writer as saying that "the conditions at the mouth of the Colorado present a nearly stable equilibrium," and that "the whole littoral, from the highlands at the mouth of the Colorado to the present canal mouth, is in a condition of constant accretion," and considers these statements as contradictory. The writer fails to see any contradiction therein, as he states plainly that the accretions commence at the Colorado, where they are zero, and extend to Greytown, where they are known and admitted to be immense.

Now, a word as to littoral currents: These currents, as shown on navigation charts, are apt to be misleading to the engineer, and their value to him, as part of the problem of harbor or bar improvement, depends upon their distance from shore. Where there exists a strong littoral current, a mile or two off shore, running in a certain direction, there is almost sure to be a surf race in the opposite direction, as is the case on the Florida east coast,* the coast of Honduras and at other places, which have come under the writer's personal observation. This is the case here. These contrary currents are in the nature of an eddy, and partially restore the equilibrium of the water. This accounts, also, for the current running in the face of the trade winds, which puzzles Mr. Noble. The writer has often observed this on flat,

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* *Transactions*, Am. Soc. C. E., Vol. xliii, p. 95.

Mr. Le Baron.

sandy coasts. It is only in this way that the equilibrium of the sea can be restored. Wherever the sand comes from, it is certain that at Greytown it is continually traveling northwest into the bight of the coast line. This movement was reported by the English engineers, Passamore and Climie, who made a survey of Greytown Harbor for the Nicaraguan Government in 1874, and whose report was published in Spanish by that Government. This survey was made to devise a plan for restoring the Harbor of Greytown, and in it they advocate deepening and jettying the mouth of the lower San Juan River, cutting off the flow from the Harbor of Greytown, which was to be entered from the river by a tide-lock, they arguing that the increased volume and velocity of the outflowing current would form a "breakwater of water" (*rompolas de agua*), which would arrest this sand drift and thus preserve an open entrance for the harbor to the westward. Just how this would be accomplished was not made clear.

In regard to the alignment south of the San Juan, Mr. Noble considers that "it is not likely that it would be materially better than that now obtained on the left bank," and states that "the divide is about 50 miles distant." Just what is meant by the "divide" is not quite clear, but it is immaterial. The important matter is the width of the intervale or river bottoms, and this is known to be wider on the south side.

It is known that Colonel Childs supposed that the high hill on the south side of the San Juan and east of the mouth of the Serapiqui was a spur from the Costa Rican Mountains, and he based his project of canalization of the San Juan River on this supposition.

Later reconnoissances proved this to be an isolated hill, with a large and unknown extent of swamp behind it, thus making it impossible to canalize the San Juan by means of a high dam at this point, as proposed by Colonel Childs. Still later, it was hoped, during the several surveys made by the Nicaragua Canal Company, and by the United States, that spurs suitable for this purpose could be found opposite San Francisco Island or Tamborcito and other places, and various examinations were made of the south side for the purpose of discovering such spurs; but all proved futile. These various surveys have demonstrated that the river bottoms on the south side extend many miles south of the river, being dotted with only occasional isolated hills, whereas on the north side, as first stated, the mountain spurs of the Cordilleras come abruptly down to the river in numerous places, and have to be cut through by any line on that side. These facts support the writer's contention that on the south side a very much better alignment can be found than exists on the north side, and the engineer is justified in being more sanguine of finding "captivating tangents" when all the facts demonstrate that the ground for them exists. The experience of large ships in the curves of the Suez Canal shows conclusively the importance of these "captivating tangents,"

Mr. Le Baron. even at the expense of more costly works at the crossing of the Serapiqui. The writer repeats, enough is known of the topography of the south side to justify the belief that the alignment can be bettered nearly 75% on that side; and, while the line, as laid down on the writer's map, may very likely have to be shifted in places, the surveys already made show that no material change need be expected or looked for, as this line is laid down in accordance with known and accurately delineated topography.

The comparison made by General Hains between the anchor chains of a light-ship and the net chains enclosing the rock-filled dam is not appropriate. The anchor chains of a ship are continually in motion, being dragged about on the ocean floor while the ship is tugging and straining at her anchor, whereas the chains enveloping the rock-filled dam will lie almost quiescent, being held firmly in place by the rough rocks composing the dam itself, and, in turn, holding those rocks. Where the ship's chain is continually grinding up the sand between each link and thus always abrading every wearing surface, the net chains will lie quietly in the dam, covered by the rough stones, and only exposed to the abrading action of such sand as is brought against it at a few exposed points, and it will occur to anyone that this chain net can be carried clear across the dam, during the process of construction, every 10, 20 or 30 ft. in height, if desired, and so connected by split links, up and down and right and left, as to form in reality a number of nets all connected together, so that if it should be worn away at one place it will be held in another a few feet distant, perfectly protected by the enclosed and superincumbent rock. This also answers the next question as to how loose stone will be held on the down-stream slope during a great flood. In other words, there will not be a single net or bag, but a series of nets, one above the other, and all linked together. Neither will it be necessary, as will occur to any practical engineer, to draw the chain up against the stream, but it can be drawn down with the current, and thus spread over the rock.

The rusting of iron or steel under water in the course of ages is, of course, admitted, but in fresh water this is a comparatively slow process. If, for this reason, engineers are to be deterred from using it, three-fourths of the engineering constructions of the present day, such as steel caissons for bridges, piers, etc., must be condemned. A little reflection will show that when these cables are rusted out, a new chain net can very easily be spread over the dam, which, by that time, however, will have become consolidated and stable, except possibly on the crest.

The Conchuda Dam is to be of masonry, and General Hains says this is "perfectly safe and practicable." This cannot be said truthfully of any masonry construction in an earthquake country. As General Hains says, somewhat sarcastically, "a rock-fill dam is the only dam known that is improved by earthquakes," and quotes the **Mr. Le Baron.** writer as saying that "an earthquake would only serve to consolidate it and fill up the voids." The writer repeats that this is his opinion, but he does not claim credit for its originality. This feature of a rock-fill dam at Ochoa was advanced as a favorable one by the consulting engineers who reported on it several years ago. To trust the fate of the canal to a masonry dam, anywhere on the Isthmus, would, in the writer's opinion, be taking chances that no prudent engineer would care to take if they could possibly be avoided. The comparison of the wearing effect of sand in the bends of a centrifugal pump, having a velocity of 15 to 20 ft. per second in a closed tube, with that of a river current having a velocity of 4 to 8 ft. per second seems rather far fetched. Such terrible abrasion General Hains fears would wear away the crest of his masonry spillways in a short time. The amount of sand abrasion of a wrought-iron rod set in a smooth ledge close to a sand beach, in salt water, at the mouth of a tidal river where the tide-rip, heavily charged with sand, swept over the ledge with a velocity of 2 to 8 ft. per second, was at the rate of 1 in. in twenty years, as observed by the writer. In fresh water it would be less, and it may be safely placed at 1 in. in twenty-five years.

As a matter of fact, because a rock-fill dam is built at Ochoa, it does not follow that it must be built as a weir. The writer believes, as he stated in the paper, that a dam constructed as proposed would be perfectly safe as a weir, but it is not obligatory to build it as a weir. The dam can be built there, as at Conchudo, above the highest floods, and all the discharge of the river taken over the San Carlos spillways.

The location of a rock-fill dam at Ochoa has been favorably passed upon by two Boards of Consulting Engineers, and, with some modifications, accepted by the United States Canal Board, the first consisting of the Canal Company's engineers, Commander A. G. Menocal, Civil Engineer, United States Navy, Chief Engineer; Lieutenant (now Commander) R. E. Peary, Civil Engineer, United States Navy, Sub-Chief Engineer; the late E. P. Davis, Assistant Engineer, and the writer, at that time Principal Assistant Engineer. At that time more than eight months had been spent in studying the conditions on the ground.

The second Board consisted of well-known engineers, of high standing, not connected with the Canal Company. Of this Board, the late A. M. Wellington, M. Am. Soc. C. E., was Chairman.

The fact that a rock foundation is not known to exist in the San Carlos Ridge, only emphasizes the writer's contention that the south side of the river should be carefully examined and the line surveyed before construction is commenced, in order to compare properly the relative merits of the two plans, which was the only object of the paper; the facts, as the writer believes and so stated, warranting a survey of a route on the south side.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final Publication.

HENRY LAWRENCE CLEVERDON, Assoc. M. Am. Soc. C. E.*

DIED AUGUST 27th, 1902.

Henry Lawrence Cleverdon, known to the members of his family and to his most intimate friends as "Lonnie," was born at Washington, D. C., on April 6th, 1869. At the age of fifteen his parents returned to their former home, Chagrin Falls, Ohio, 18 miles southeast of Cleveland, and here he completed his common school education, and was graduated from the high school in 1888.

Being naturally an energetic boy, with an extremely practical turn of mind, and having decided early upon his life's work, he utilized his vacations, while still in the high school, as best he could to advance himself in his chosen profession. During the summer of 1887 he worked as Chainman for Mr. J. F. Brown, a Cleveland surveyor, and from April, 1888, until September, 1889, as Rodman on the Lake Shore and Michigan Southern Railway. While engaged on the latter work he came to realize the importance and value of a better education, and resigned to enter the University of Michigan as a student in the Engineering Department.

College work was always hard work with him—the means to an end—and, although he mastered his various studies with credit to himself, he chafed under too much confinement and longed for active outdoor life.

From July, 1890, to January, 1891, he served as Instrumentman and Resident Engineer on the construction of the Akron and Chicago Junction Railway (Ohio), now the Baltimore and Ohio Railway, and returned to college as soon as the work was finished. During the construction of the Wilkes Barre and Eastern Railway, through the mountains of Eastern Pennsylvania, Mr. Cleverdon was employed as Locating or Resident Engineer, from the beginning to the completion of the work, and some of the most difficult construction was under his direct charge. He expected to return to college and be graduated with his class—the class of '93—but one job after another came and was completed in such rapid succession that there seemed to be no time for anything else, and at last he gave up all thoughts of trying to return.

He served as Rodman on topographical surveys for the Short Line

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* Memoir prepared by George H. Fenkell, Assoc. M. Am. Soc. C. E.

Improvement Company (Pennsylvania) from January to June, 1894, and from August, 1894, until April, 1895, was Resident Engineer, in charge of construction of six miles of the Fort Plain and Richfield Springs Railway (New York); but when the latter road was nearly ready for the track work was suspended, and Mr. Cleverdon, together with the other members of the engineering corps, was defrauded out of several months' salary, an incident that made him much wiser, if somewhat poorer. That he was not afraid of hard work, is shown by his serving first as laborer and then as Foreman and Superintendent for a water-works contractor at Fort Plain, New York, during the summer of 1895. During the autumn and winter of 1895–6 he was employed as an engineer on street railways and suburban electric lines in and near Cleveland, Ohio, and was Engineer in charge of the construction of three miles of a brick-paved highway for the County of Cuyahoga, Ohio.

From September, 1896, to October, 1897, Mr. Cleverdon was Resident Engineer in charge of construction of six miles of the Lorain and Cleveland Electric Railway, one of the first electric roads in the Middle States to be constructed in accordance with the best steam-road practice. In June, 1898, he was Locating Engineer for the Rapid Railroad, on a proposed line from Detroit to the St. Clair Flats, Michigan; and from August to November, 1898, Assistant Engineer on the Chicago and West Michigan Railroad, principally in charge of masonry construction.

He began work as Resident Engineer on the Cleveland and Eastern Railroad in January, 1899, but resigned in March, 1899, and in April began work as Division Engineer in charge of construction on the Copper Range Railroad, in Northern Michigan. This work was finished in June, 1900, and he at once accepted the position of Chief Engineer of the St. Johns and St. Louis Electric Railroad, Michigan, under the direction of the Arnold Electric Power Station Company, of Chicago, and remained there until the road was completed, in February, 1902.

For the next three months he was Resident Engineer on the Cleveland Water-Works Tunnel, and resigned this position to become Deputy County Surveyor of Cuyahoga County, Ohio, in charge of all bridges in that county.

On June 16th, 1902, he was married to Miss Elsie L. Williams, of Glenville, Ohio, and they at once began housekeeping in their new home, on the shore of Lake Erie, about 14 miles west of Cleveland. It then seemed as if his happiness was complete—a home, a loving wife, and a permanent position were appreciated all the more after fifteen years of the most active kind of work.

On the morning of August 23d, 1902, he boarded a car going toward Cleveland and requested the conductor to let him off at a farm road crossing about two miles farther east, to enable him to inspect a county bridge located near the car line. For some reason not known, the car passed by the cross-road and finally came to a stop on a wooden trestle 50 ft. high, a trestle that Mr. Cleverdon had constructed in 1897 while Engineer in charge of the construction of this road—the Lorain and Cleveland. When the car stopped he swung off on to the trestle and began to walk away from the rear end of the car. The car started, but he supposed it had resumed its journey and gave it no further attention. As a matter of fact, the car was backing up, and the first warning he had of the impending danger was when it struck him. He partly jumped and was partly knocked from the trestle, struck a cross-timber on his descent and then dropped to the ground. When picked up a few moments later, in a semi-conscious condition, both limbs were found to be broken between the knees and hips.

He was taken to St. John's Hospital in the same car that struck him, an operation performed, his wife and family summoned and everything possible done to allay his sufferings and improve his condition. He did not seem to rally, however, and on August 27th, 1902, ten weeks after his wedding day, he passed away. The funeral was held the next day at his old home, Chagrin Falls, Ohio.

Mr. Cleverdon was a noble-hearted man, true to his friends and beloved by them in return. Always active and energetic, he had a wide circle of friends, scattered from one end of the country to the other, who mourn his untimely death.

He is survived by his wife, by his parents, one sister and four brothers.

Mr. Cleverdon was elected an Associate Member of the American Society of Civil Engineers on March 1st, 1899.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XXIX. No. 2.
FEBRUARY, 1903.

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NEW YORK 1903.

Entered according to Act of Congress, by the AMERICAN SOCIETY OF CIVIL ENGINEERS, in the office of the Librarian of Congress, at Washington.

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The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER, - - - 583 Columbus.
CABLE ADDRESS, - - - - "Ceas, New York."

Vol. XXIX. FEBRUARY, 1903. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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MINUTES OF MEETINGS.

OF THE SOCIETY.

FIFTIETH ANNUAL MEETING.*

January 21st, 1903.—The meeting was called to order at 10.45 A. M., Vice-President Charles C. Schneider in the chair; Charles Warren Hunt, Secretary.

The reading of the minutes of the meeting of January 7th, 1903, was dispensed with.

Messrs. G. S. Stoddart and C. D. Pollock were appointed tellers to canvass the Ballot for Officers for the ensuing year.

The Annual Report of the Board of Direction† and the Annual Reports of the Secretary† and of the Treasurer† for the year ending

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* A full report of the Fiftieth Annual Meeting is printed on pages 42 to 80 of this number of *Proceedings*.

† The Annual Reports of the Board of Direction, the Secretary and the Treasurer may be found on pages 5 to 14 of the *Proceedings* for January, 1903 (vol. xxix).

December 31st, 1902, were presented, and, on motion, duly seconded, accepted.

The Progress Report of the Special Committee on Uniform Tests of Cement* was presented by George S. Webster, M. Am. Soc. C. E., Chairman of that Committee.

At 11.20 A. M. the chair was taken by President Robert Moore.

On motion, duly seconded, the report was received and ordered printed in *Proceedings*, and the Committee continued.

On motion, duly seconded, the Committee was thanked for its labor and report.

A progress report from the Special Committee on Rail Sections was presented by L. F. G. Bouscaren, M. Am. Soc. C. E., Chairman of that Committee.

On motion, duly seconded, the Committee was continued.

The following were appointed members of the Nominating Committee for two years:

George W. Tillson	Representing	District	No.	1.
J. P. Snow	"	"	"	2.
Edward A. Bond	"	"	"	3.
Richard Khuen, Jr	"	"	"	4.
L. E. Chapin	"	"	"	5.
John B. Atkinson	"	"	"	6.
D. C. Henny	"	"	"	7.

The Secretary reported that the Board of Direction had awarded the prizes for the year ending with the month of July, 1902, as follows:

The Norman Medal to Paper No. 911, entitled, "Experiments at Detroit, Mich., on the Effect of Curvature upon the Flow of Water in Pipes," by Gardner S. Williams, M. Am. Soc. C. E.; Clarence W. Hubbell, Assoc. M. Am. Soc. C. E., and George H. Fenkell, Jun. Am. Soc. C. E.

The Thomas Fitch Rowland Prize to Paper No. 910, entitled, "Description of Coos Bay, Oregon, and the Improvement of Its Entrance by the Government," by William W. Harts, M. Am. Soc. C. E.

The consideration of the following proposed amendment to the Constitution was then taken up:

Amend Article III of the Constitution as follows:

Section 2, first line, after the words "Society as" strike out the words "Member or as Associate" and insert the words "a Corporate"; second line, after the word "to" strike out the words "either grade of."

Section 2, Art. III, will then read, "An application for admission to the Society as a Corporate Member, or for transfer from any other grade to Corporate Membership shall embody," the rest of the section standing as now.

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* This report is printed in *Proceedings* for January, 1903.

Section 3, third line, after the word "membership" strike out the words "in any grade," and after the word "transfer" strike out the words "from one grade to another"; twelfth line, for the word "may" substitute the word "shall." The section will then read as follows:

"At stated periods, to be determined by the Board of Direction, there shall be issued to each member in any grade whose address is known, a list of all new applications received for membership or for transfer, which list shall be dated and shall contain a concise statement of the record of each applicant and the names of the references in the case of Corporate Member, and endorsers in the case of Associate, Junior or Fellow, with a request that members transmit to the Board any information in their possession which may affect the disposition of the applications. Not less than twenty days after the issue of such list, the Board of Direction shall consider these applications together with any information in regard to the applicants that may have been received; may make further inquiries, if deemed expedient; shall classify the applicant with his consent, and on applications for Corporate Membership may direct a ballot."

This amendment was proposed by Messrs. H. G. Prout, G. S. Williams, Alf. P. Boller, Geo. Y. Wisner and Geo. F. Swain, and was sent to all Corporate Members on October 2d, 1902.

The amendment was discussed, but was not amended.

A resolution,* relative to the death of Abram S. Hewitt, was offered by George S. Morison, Past-President, Am. Soc. C. E., seconded by Robert W. Hunt, M. Am. Soc. C. E., and carried unanimously.

J. A. Ockerson, M. Am. Soc. C. E., offered the following resolution:

Resolved, That it is the sense of this meeting that the American Society of Civil Engineers should co-operate with the officers of the Louisiana Purchase Exposition Company, in the inauguration of an International Congress of Engineering, to be held in St. Louis, during the Exposition period of 1904, and be it further

Resolved, That the Board of Direction be, and is, hereby, authorized and requested to take such steps as may be necessary to carry out the provisions of the foregoing resolution.

The resolution, being duly seconded, was carried.

The Secretary presented the report† of the tellers appointed to canvass the Ballot for Officers for the ensuing year.

The President announced the election of the following officers:

President, to serve one year:

ALFRED NOBLE, New York City.

Vice-Presidents, to serve two years:

L. F. G. BOUSCAREN, Cincinnati, Ohio.
JAMES D. SCHUYLER, Los Angeles, Cal.

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* See page 70.

† See page 72.

Treasurer, to serve one year:
JOSEPH M. KNAP, New York City.

Directors, to serve three years:
District No. 1.—ALFRED CRAVEN, Yonkers, N. Y.
District No. 1.—JOSEPH O. OSGOOD, Plainfield, N. J.
District No. 4.—GEORGE S. DAVISON, Pittsburg, Pa.
District No. 6.—E. C. LEWIS, Nashville, Tenn.
District No. 6.—HUNTER McDONALD, Nashville, Tenn.
District No. 7.—ELWOOD MEAD, Cheyenne, Wyo.

Mr. Morison and Mr. Croes conducted Mr. Noble, the President-elect, to the chair.

The Secretary read a letter from Robert Moore, Past-President, Am. Soc. C. E., to the effect that, in pursuance of the resolution passed at the last Annual Convention an oak tree had been planted at Mt. Vernon as a memorial of the visit of the Society in May, 1902; and that this work had been executed by Messrs. Gifford Pinchot and George B. Sudworth, of the Bureau of Forestry, and Harrison H. Dodge, Superintendent of the Mt. Vernon Estate.

It was moved, duly seconded and carried that the Secretary be instructed by this meeting to extend the thanks of the Society to the gentlemen named for executing this commission.

Adjourned.

February 4th, 1903.—The meeting was called to order at 8.50 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, 100 members and 20 guests.

The minutes of the meeting of January 7th, 1903, were approved as printed in *Proceedings* for January, 1903. The approval of the minutes of the Annual Meeting was deferred until they are printed in the *Proceedings* for February, 1903.

An informal discussion on "The Preservation of Materials of Construction," was opened by William Barclay Parsons, M. Am. Soc. C. E., who exhibited perfectly preserved specimens of wood taken from the excavation for the Metropolitan Underground Railway of Paris at the site of the ancient "Porte du Temple," founded during the reign of Charles V, 1364–1380. He also showed a section of wooden water pipe, taken from the excavation for the New York Rapid Transit Subway on Center Street, which had been in the ground about 100 years, and yet was perfectly preserved. The Secretary presented a letter from Mr. James Forgie, Chief Assistant Engineer of the City and South London Deep Underground Railways, transmitting and describing a piece of iron about 200 years old, in the form of a masonry cramp or bonding iron, on which no trace of rusting could be seen. The iron had been found, in 1899, embedded in the sandstone masonry of a pier in the crypt of St. Mary Woolnoth Church, in London, where the foundations of a railroad depot were being made. The letter was accompanied by a photograph of the crypt, showing the place where the iron was found. Rudolph P. Miller, Assoc. M. Am. Soc. C. E., described the condition of the metal in a large building of modern construction, in New York City, which is now being taken down, and illustrated his remarks with lantern slides.

The subject was discussed further by Messrs. George Hill, W. W. Kenley, George A. Just, Edward P. North, Oscar Lowinson and Henry B. Seaman.

Ballots for membership were canvassed, and the following candidates were elected:

As Members.

Harry Sherman Bosler, Akron, Ala.
George Elvin Datesman, Philadelphia, Pa.
Arthur James Dyer, Nashville, Tenn.
William Henry Finley, Winnetka, Ill.
Graham Denby Fitch, Little Rock, Ark.
Isham Randolph, Chicago, Ill.
Charles Winslow Sherman, Boston, Mass.
Henry Clark Thompson, New York City.
George Monroe Wisner, Chicago, Ill.

As Associate Members.

James Marcus Bandy, Greensboro, N. C.
Edward Christian Henry Bantel, Austin, Tex.
Sam Wigfall Bradshaw, Steelton, Pa.
Per Brynn, Pittsburg, Pa.
Harris De Haven Connick, San Francisco, Cal.
Richard Turner Dana, Ridgewood, N. J.
Edward Bliss Day, St. Louis, Mo.
Horace De Remer Haight, Albany, N. Y.
Joseph Milton Howe, Houston, Tex.
Henry Scudder Jaudon, Birmingham, Ala.
George Albert McKay, Newport, R. I.
Hibbard Atwill Paine, Chandler, Okla. T.
William Edwin Pincombe, Calcutta, India.
James Vincent Rockwell, Eagle Grove, Iowa.
Edward Moses Stayton, Hope, Ark.
Lazarus White, New York City.

The Secretary announced the election of the following candidates by the Board of Direction on February 3d, 1903:

AS ASSOCIATES.

RUDOLF CASPAR CARL MARIE BERNEGAU, New York City.
OTTO BALTHAZAR KELLER, New York City.
EUGENE MCGRATH QUIRK, Montreal, Que., Canada.

AS JUNIORS.

JOHN SEAGER ADEY, New York City.
ROBERT JAY BASSETT, Steelton, Pa.
JOHN ANTHONY CROOK, Falls City, Neb.
SHUKICHI FUJINO, Pencoyd, Pa.
HUGH MELVIN GEORGE, Meridian, Miss.
FREDERICK APPEL HAUSMAN, Bridgeport, Pa.
VERNET ALBERT KAUFFMAN, Alamogordo, N. Mex.
HENRY JACOB KOLB, Steelton, Pa.
GEORGE EDSON PHILIP SMITH, Tucson, Ariz.
TRAVIS LOGAN SMITH, Jr., Fulshear, Tex.
CHARLES UNDERHILL STEPATH, New York City.
CARL TOMBO, New York City.
EDWARD LLOYD WALKER, Paterson, N. J.
EZRA BAILEY WHITMAN, New York City.
WALDO GILMAN WILDES, Clinton, Mass.
BENJAMIN LEE WILLIAMS, Jr., West Orange, N. J.
CAROLUS HERMANN ZANE-CETTI, Fort Worth, Tex.

The Secretary announced the death of the following members:

WATSON WELLMAN RICH, elected Member September 5th, 1883; died January 12th, 1903.

ESTEVAN ANTONIO FUERTES, elected Member February 17th, 1869; died January 16th, 1903.

ELNATHAN SWEET, elected Member November 6th, 1878; died January 27th, 1903.

Adjourned.

February 18th, 1903.—The meeting was called to order at 8.50 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, 121 members and 35 guests.

A paper entitled, "The Panama Canal," by George S. Morison, Past-President, Am. Soc. C. E., was presented by the author, and illustrated with lantern slides.

A written communication on the subject, by M. Meigs, M. Am. Soc. C. E., was presented by the Secretary.

The subject was discussed orally by Messrs. Theodore Paschke, W.

H. Burr, C. L. Harrison, Boyd Ehle, W. E. Crane, P. Bunau-Varilla and the author.

The Secretary announced the death of JOHN WALKER BARRIGER, Jr., elected Junior May 31st, 1898; Associate Member, April 2d, 1902; died December 19th, 1902.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

January 21st, 1903.—2.30 P. M.—President Noble in the Chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Buck, Craven, Davison, Jackson, Knap, Moore, Osgood, Pegram, Schneider, Swain and Wilgus.

A Committee on Finance, a Library Committee, a Committee on Publications, and a Committee on Membership, were appointed.

A letter-ballot was ordered for the election of a Secretary for the ensuing year.

Adjourned.

February 3d, 1903.—8.40 P. M.—President Noble in the Chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Craven, Croes, Endicott, Knap, Kuichling, Osgood, Swain and Wilgus.

The ballot for Secretary was canvassed, by tellers appointed for the purpose, and Chas. Warren Hunt was declared elected.

The resolution, passed at the Annual Meeting, recommending cooperation with the officers of the Louisiana Purchase Exposition Company, in the matter of a proposed International Congress of Engineering, to be held in St. Louis during the Exposition of 1904, was referred to a Special Committee of the Board.

The resignations of Horace See, M. Am. Soc. C. E., and C. W. Walton, M. Am. Soc. C. E., were accepted.

A Committee of the Board was appointed to take up the matter of a proposed revision of the rules for the award of the Collingwood Prize for Juniors.

Applications were considered, and other routine business transacted.

Three candidates for Associate and seventeen for Junior were elected.*

Adjourned.

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* See page 40.

REPORT IN FULL OF THE FIFTIETH ANNUAL MEETING, JANUARY 21st and 22d, 1903.

Meeting called to order.

Wednesday, January 21st, 1903.—The meeting was called to order at 10:45 A. M.; Vice-President C. C. Schneider in the chair; Charles Warren Hunt, Secretary.

THE CHAIRMAN.—The minutes of the meeting of January 7th, 1903, will be printed in the January number of *Proceedings*, and come up in due course for action at the meeting of February 4th. In view of this fact, the reading of those minutes will be dispensed with, if there are no objections.

Tellers appointed.

The time has arrived now for canvassing the votes for officers, and I will appoint Messrs. G. S. Stoddard and C. D. Pollock as tellers. The ballot will be closed, in accordance with the Constitution, at twelve o'clock noon. Any member present who has not voted may vote, up to that time. In order to finish the count of the ballot in time, the tellers may proceed at once with the count.

The next business is the reading of the report of the Board of Direction for 1902.

Report of the Board of Direction.

The Secretary read the report of the Board of Direction.*

THE CHAIRMAN.—You have heard the report of the Board of Direction. What action will you take?

A MEMBER.—I move that the report be received and placed on file.

Seconded and carried.

THE CHAIRMAN.—The report of the Secretary to the Board of Direction.

The Secretary read his report.†

THE CHAIRMAN.—You have heard the Secretary's report. What action will you take in reference to it?

It was moved and seconded that the report be received and placed on file.

Carried.

THE CHAIRMAN.—The report of the Treasurer.

The Treasurer read his report.‡

THE CHAIRMAN.—Gentlemen, what action will you take with reference to the Treasurer's report? If there are no objections, it will be received and placed on file.

Reports of Special Committees.

The report of the Special Committee on Uniform Tests of Cement, Mr. Geo. S. Webster, Chairman.

Report read by Mr. Webster.§

(At 11.20 A. M. the chair was taken by the President, Mr. Robert Moore.)

THE PRESIDENT.—You have heard the report, and it is now open for discussion or for such action as the meeting sees fit to take.

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* See *Proceedings*, Vol. xxix, p. 5 (January, 1903).

† See *Proceedings*, Vol. xxix, p. 12 (January, 1903).

‡ See *Proceedings*, Vol. xxix, p. 14 (January, 1903).

§ See *Proceedings* for January, 1903.

J. James R. Croes, Past-President, Am. Soc. C. E.—I move that the report be received and printed in the *Proceedings*, and the Committee continued.

Seconded and carried.

E. B. Codwise, M. Am. Soc. C. E.—I move that the Committee be thanked for their labor and their report.

Seconded and carried.

The President.—The next thing in order is the report from the Committee on Rail Sections; Mr. Bouscaren, Chairman. I believe he has a progress report.

The report was read by Mr. Bouscaren as follows:

"The Special Committee on Rail Sections would report that it has made progress in its labors; has been and is in correspondence with the Chief Engineers of many of the railroads of the United States and Canada; and that the reports received from them show greater proportionate wear of the heavier than of the lighter sectioned rails.

"They would also report that the steel rail manufacturers of the United States have appointed a committee to act in consultation with your committee, and that one joint session has been held. Your committee asks to be continued."

"G. Bouscaren,
"*Chairman.*"

The President.—You have heard the report, gentlemen, and also the request of the Committee that they be continued. What action will you take?

Mr. Codwise.—I move that the request be granted.

Seconded and carried.

Nominating Committee.

The President.—The next order of business is action upon the nominations for the seven geographical districts for members of the next Nominating Committee. We will hear the reports of the nominations which have been made by the members of those districts.

The Secretary.—The report from District No. 1 is as follows:

District No. 1.—Total number of votes received, 98; distributed as follows:

George W. Tillson	24
Frederick S. Odell	19
Henry W. Hodge	16
C. H. Graham	3
George S. Rice	3
J. V. Davies	2
J. J. R. Croes*	2
George B. Francis	2
Charles S. Gowen	2
Allen Hazen	2
O. F. Nichols	2
T. Kennard Thomson	2
S. C. Thompson	2

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* Ineligible.

Nominating Committee (Continued).

The following have received one vote each:

Wm. Henry Baldwin,
William H. Burr,
S. L. F. Deyo,
William B. Fuller,
Martin Gay,
S. W. Hoag, Jr.,
George A. Just,
Henry P. Morrison,
Edward P. North,
John F. O'Rourke,
E. E. Olcott,
J. Waldo Smith,
M. G. Starrett,
Edward Wegmann,
S. C. Weiskopf,
W. J. Wilgus,*
F. Stuart Williamson.

The Secretary.—The members of the Nominating Committee are to be elected by this meeting, and this is merely a suggestion to the meeting.

The President.—The Chair awaits suggestions in that matter, as to the pleasure of the Society.

J. M. Knap, Treasurer, Am. Soc. C. E.—I move that the usual course be adopted, and that we elect the man who receives the largest number of votes, who, I think, in this case, is Mr. Tillson.

Seconded.

The President.—It is moved and seconded that Mr. Tillson be the choice of the meeting for this district.

Carried.

The Secretary.—From District No. 2 the report is as follows:

District No. 2.—Total number of votes received, 42; distributed as follows:

J. P. Snow	11
Clarence B. Vorce	8
George A. Kimball *	4
Frederic P. Stearns	4
C. Frank Allen	2
S. E. Tinkham	2

The following have received one vote each:

A. S. Cheever,
Freeman C. Coffin,
Desmond FitzGerald,*
George B. Francis,*
Arthur W. French,
George R. Hardy,
C. M. Ingersoll,
Leonard Metcalf,
Mace Moulton,
Edward Sawyer,
George F. Swain.*

C. S. Allen, M. Am. Soc. C. E.—I move that Mr. J. P. Snow be elected on the Nominating Committee.

Seconded and carried.

The Secretary.—The District No. 3 report is as follows:

District No. 3.—Total number of votes received, 66; distributed as follows:

Edward A. Bond	29
Palmer C. Ricketts	19
Charles M. Morse	2
P. Alexander Peterson	2
Gardner S. Williams	2

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* Ineligible.

The following have received one vote each:

John F. Alden,*
Frank V. E. Bardol,
E. E. Brydone-Jack,
Robert Cartwright,
Clark Fisher,
William A. Haven,
John Kennedy,
Louis H. Knapp,
Olin H. Landreth,
E. H. McHenry,
Elnathan Sweet,
T. W. Symons.

The President.—Is there any motion?

Mr. E. B. Codwise.—I move that Mr. Edward A. Bond, having received the highest number of votes on the ballots, be declared elected.

Seconded and carried.

The Secretary.—The ballot from District No. 4 is as follows:

District No. 4.—Total number of votes received, 107; distributed as follows:

Richard Khuen, Jr.	47
L. Y. Scherмerhorn	22
H. M. Wilson	17
Bernard R. Green	2
Emil Swensson	2

The following have received one vote each:

Edward M. Bigelow,
William Bradford,
W. W. Card,
Arthur P. Davis,
George S. Davison,*
J. E. Greiner,
G. B. Hazlehurst,
John W. Hill,
N. H. Hutton,
Harvey Linton,
F. O. Maxson,
Mansfield Merriman,
William A. Pratt,
E. B. Taylor,
S. La R. Tone,
Samuel Tobias Wagner,*
George S. Webster.

The President.—Richard Khuen has the largest number of votes. It is moved and seconded that his election be made unanimous. Carried.

The Secretary.—District No. 5 votes:

District No. 5.—Total number of votes received, 79; distributed as follows:

L. E. Chapin	25
J. B. Davis	8
William M. Hughes	6
R. B. C. Bement	3
G. A. Marr	3
John W. Alvord	2
Charles E. Greene	2
D. W. Mead	2
C. J. A. Morris	2
Samuel T. Wellman	2

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* Ineligible.

Nominating Committee (Continued).

The following have received one vote each:

Ward Baldwin,
L. F. G. Bouscaren,*
George H. Boynton,
W. M. Camp,
D. D. Carothers,
E. C. Carter,*
Clarence Coleman,
F. A. Delano,
James Dun,
R. L. Engle,
E. E. Haskell,
G. W. Kittredge,
Charles F. Loweth,
Ralph Modjeski,
G. B. Nicholson,*
Walter P. Rice,
H. E. Riggs,
James Ritchie,
J. W. Schaub,
E. C. Shankland,
Charles L. Strobel,
Job Tuthill,
L. L. Wheeler,
George Y. Wisner.

On motion, duly seconded, Mr. L. E. Chapin was elected as member of the Nominating Committee.

The Secretary.—District No. 6:

District No. 6.—Total number of votes received, 46; distributed as follows:

John B. Atkinson	5
Arthur Hider	3
J. A. L. Waddell	3
George G. Earl	2
L. F. Goodale	2
B. M. Harrod	2
C. D. Purdon	2
S. Bent Russell	2

The following have received one vote each:

James P. Allen,
William Cain,
W. W. Carson,
William H. Courtenay,
William P. Craighill,
Ben. L. Crosby,
Edward Flad,
B. M. Hall,
W. J. Hardee,
W. N. Hazlehurst,
E. C. Lewis,*
J. L. Ludlow,
D. W. Lum,
R. C. McCalla,
Hunter McDonald,*
F. A. Molitor,
R. Montfort,
Geo. B. Nicholson,
J. A. Ockerson,
M. P. Paret,
Hiram Phillips,
A. M. Scott,
B. F. Thomas,
C. C. Wentworth,
José R. Villalon.

The President.—Mr. John B. Atkinson has the largest number of votes. Is there any motion? If not, those who are in favor of the election of John B. Atkinson will say aye.

Carried.

The Secretary.—District No. 7:

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* Ineligible.

District No. 7.—Total number of votes received, 44; distributed as follows:

D. C. Henny	9
C. E. Grunsky	4
C. D. Marx	4
Roberto Gayol	2
Horace A. Sumner	2
A. J. Tullock	2
Otto von Geldern	2

The following have received one vote each:

W. A. Aycrigg,
Julius Baier,
R. E. Briggs,
R. B. Burns,
E. B. Cushing,
George L. Dillman,
H. W. Edwards,
C. F. W. Felt,
W. W. Follett,
C. E. Fowler,
Arthur DeWitt Foote,
F. W. D. Holbrook,
John D. Isaacs,
W. H. Kennedy,
J. B. Lippincott,
J. W. Maxey,
D. W. Ross,
W. B. Storey, Jr.,
James D. Schuyler.*

The President.—Mr. D. C. Henny has the largest number of votes. Those who are in favor of making him a member of the Nominating Committee signify by saying aye.

Carried.

Award of Prizes.

The President.—This concludes that order of business. The next is the report from the Board of Direction as to the award of the medal and prizes for the year ending with July, 1902.

The Secretary.—I am directed by the Board of Direction to report that the Norman Medal and the Thomas Fitch Rowland Prize have been awarded by the Board, in accordance with the recommendations of the following report:

To the Board of Direction,
American Society of Civil Engineers.

The undersigned respectfully recommend that awards of the Normal Medal and Thomas Fitch Rowland Prize for the year ending with the *Transactions* for July, 1902, be made as follows:

The Norman Medal to Paper No. 911, "Experiments at Detroit, Michigan, on the Effect of Curvature upon the Flow of Water in Pipes," by Gardner S. Williams, M. Am. Soc. C. E.; Clarence W. Hubbell, Assoc. M. Am. Soc. C. E., and George H. Fenkell, Jun. Am. Soc. C. E.

The Thomas Fitch Rowland Prize to Paper No. 910, "Description of Coos Bay, Oregon, and the Improvement of Its Entrance by the Government," by William W. Harts, M. Am. Soc. C. E.

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* Ineligible.

Award of Prizes (Continued).

There being no papers contributed exclusively by Juniors, no recommendation as to the award of the Collingwood Prize for Juniors can be made.

Respectfully submitted,

H M. CHITTENDEN,
BERNARD R. GREEN,
G. BOUSCAREN,
Committee.

THE PRESIDENT.—This is simply for information, and requires no action. The next order of business is the proposed amendment to the Constitution, which the Secretary will read.

Proposed Amendment to the Constitution.

THE SECRETARY.—This amendment to the Constitution has now gone through all the forms, and this meeting has the power to amend it and send it out as amended; if it is not amended at this meeting, it goes to the Society in the form in which it is at present.

Amend Article III of the Constitution as follows:

Section 2, first line, after the words "Society as" strike out the words "Member or as Associate" and insert the words "a Corporate"; second line, after the word "to" strike out the words "either grade of."

Section 2, Art. III, will then read, "An application for admission to the Society as a Corporate Member, or for transfer from any other grade to Corporate Membership shall embody," the rest of the section standing as now.

Section 3, third line, after the word "membership" strike out the words "in any grade," and after the word "transfer" strike out the words "from one grade to another"; twelfth line, for the word "may" substitute the word "shall." The section will then read as follows:

"At stated periods, to be determined by the Board of Direction, there shall be issued to each member in any grade whose address is known, a list of all new applications received for membership or for transfer, which list shall be dated and shall contain a concise statement of the record of each applicant and the names of the references in the case of Corporate Member, and endorsers in the case of Associate, Junior or Fellow, with a request that members transmit to the Board any information in their possession which may affect the disposition of the applications. Not less than twenty days after the issue of such list, the Board of Direction shall consider these applications, together with any information in regard to the applicants that may have been received; may make further inquiries, if deemed expedient; shall classify the applicant with his consent, and on applications for Corporate Membership may direct a ballot."

THE PRESIDENT.—The matter is open for discussion, gentlemen.

J. F. O'ROURKE, M. Am. Soc. C. E.—I would like to offer this amendment as a substitute for the amendment just read.

The Secretary read the amendment offered, as follows:

Proposed Amendment to the Constitution.

Amend A ticle III of the Constitution as follows:

Strike out the first seven sections of Article III, and substitute the following:

1. Election to membership in all grades shall be by the Board of Direction, subject to the following procedure:

2. Honorary Members shall be proposed by at least ten members, and shall be elected only by a unanimous vote of the Board of Direction. A Past-President, or a member of the Board of Direction proposed for Honorary Membership, shall not be required to vote either for or against his own admission.

A person elected an Honorary Member shall be promptly notified thereof by letter. The election shall be canceled if an acceptance is not received within six months after the mailing of such notice.

3. Members, Associate Members, Associates, Juniors and Fellows, shall be elected by letter-ballot of the Board of Direction, and on such ballot three negative votes shall exclude.

4. An applicant for admission to the Society as Member or as Associate Member, or for transfer from any other grade to either grade of Corporate Membership, shall embody a concise statement, with dates, of the candidate's professional training and experience, and shall be in a form and in such detail as may be prescribed by the Board of Direction. It shall be signed by the applicant, and shall contain a promise to conform to the requirements of membership, if elected. The applicant shall furnish the names of at least five Corporate Members to whom he is personally known. Each of these shall be requested by the Secretary to address a letter to the Board of Direction, on a form prescribed by said Board, stating the extent of the writer's personal knowledge of the applicant and of his professional work. If at least five of the Corporate Members named as references do not furnish the requisite endorsement, the Secretary shall call upon the applicant for additional names, and not until written communications shall have been received from at least five Corporate Members shall the application be considered by the Board.

Applications of engineers not resident in North America, and who may be so situated as not to be personally known to five Corporate Members, may be endorsed by five Members of the Board of Direction, after having secured evidence sufficient, in their opinion, to show that the applicant is worthy of admission.

5. An application for admission as Associate, Junior, or Fellow, shall embody a statement of the applicant's qualifications for the grade of membership for which admission is sought. The application shall be signed by the applicant, and endorsed by at least three Corporate Members who shall certify that they personally know the applicant, and believe him to be in all respects a proper person to be admitted to the Society, and that they recommend him for admission.

6. At stated periods, to be determined by the Board of Direction, there shall be issued to each member in any grade whose address is known, a list of all applications received, which list shall be dated and shall contain a concise statement of the record of each applicant and the names of his references in the case of Corporate Member, and endorsers in the case of Associate, Junior or Fellow, with a request that members transmit to the Board any information in their possession which may affect the disposition of the applications. The names of applicants for admission as Member or Associate Member shall be

Discussion on Amendment to the Constitution (Continued).

alphabetically arranged as applicants for Corporate Membership, without specification as to which of these grades is sought. Not less than twenty days after the issue of such list, the Board of Direction shall consider these applications, together with any information in regard to the applicants that may have been received, and may then proceed to letter-ballot. The Society shall be notified of all elections.

Change the numbers of Sections 8, 9, 10 and 11 to 7, 8, 9 and 10, respectively.

B. R. Green, M. Am. Soc. C. E.—I second the amendment.

The President.—This amendment has been offered and seconded, and is now open for discussion or action by the meeting.

A Member.—Is it the intention of taking the vote on the amendment to the Constitution, or the amendment to the amendment, to-day?

The President.—The amendment to this proposed amendment is pending.

A Member.—As an amendment to the Constitution?

The Secretary.—It requires a letter-ballot of the whole Society; action by this meeting is merely on the form in which the amendment shall be sent out.

P. C. Ricketts, M. Am. Soc. C. E.—Mr. Chairman, it seems to me that the adoption of this amendment to the original amendment would be the defeat of the original amendment. This question of the election of members by the Board of Direction has been thoroughly considered in the past two or three years. There was a committee, as you recollect, appointed, and that committee reported, and it was defeated, as I remember, by the Society.

Now, it seems to me that the amendment proposed to-day is a good one, that is, that the classification shall be made by the Board of Direction; but the amendment to this amendment is not, in my opinion, a good one. I do not believe that the Board of Direction should have the entire charge of the affairs of the Society. I believe that, as far as the election of members of the Society is concerned, the Society is the best judge. It is true that every now and then a pink ballot comes out. They look very pink and they make an impression, but the committee appointed found—I forget the exact number, but I think it was something like thirty-two pink ballots in four or five years. It seems to me that the present method of electing members is a pretty good method and a pretty safe method. We all have a chance, those of us who are interested, to scan carefully the blue lists as they come out, and afterward the ballots, and can use our own judgment; and it is a pretty good, democratic way of doing things.

I think it would be a mistake to adopt this amendment to the amendment proposed.

H. G. Prout, M. Am. Soc. C. E.—Mr. President, as the Chairman of the committee which originally produced the amendment which has been circulated among you, it may be well for me to say two or three words. The intention of the work of our committee was simply to put the classification in the hands of the Board of Direction, as Professor Ricketts has pointed out. That is all we wished to do. We held that the Board of Direction had that power already, under the Constitution, but it did not seem quite clear that that was the case, and, therefore, the amendment which we proposed was designed to make that clear; that it was not only within the power of the Board of Direction to classify candidates, but that it was their duty. That is what our amendment was aimed to accomplish.

The amendment to that amendment which is brought forward now accomplishes that purpose, and it goes further, and puts the election in the hands of the Board of Direction. So far as that goes, I do not agree with Professor Ricketts. For many years I have held very stoutly the position that he has taken, namely, that the election should be in the great body of the Society, but within the last two or three years my feeling has changed, and I have come to believe that it would be better for the Society if the election of members were in the hands of the Directors. I should imagine that it would increase the sense of responsibility of every person who was directly interested in the election; that is to say, each member of the Board of Direction would feel that the responsibility was upon him of doing precisely the right thing. He could not soothe his conscience by knowing that there is another body to come after him, to confirm or reject his action, and surely the Board of Direction can know more precisely the fitness or unfitness of the candidate than can the great body of the members.

It is extremely difficult, I know, to get to a large body precise information very quickly, and especially negative information; but that need not be so. The Board of Direction can organize its machinery in such a way as to get more precise information, we will say, by appointing some committees among its own members to cover different territories, and take pains to get information about candidates; and my own feeling now is quite strong that the Society would get better results by having the election put in the hands of the Board of Direction.

Foster Crowell, M. Am. Soc. C. E.—Mr. Chairman, I would also support the amendment to the amendment. The matter has been before the Society quite frequently, as one of the previous speakers has mentioned, and it seems to me that this presentation is an evidence of profound reflection upon the discussions that have gone before.

Having had the opportunity to support the general idea of the policy of the election of members by the Board, in the past, I have had my feelings confirmed that that is the most practical, exact and proper method of selecting the proper material. It is not my inten-

Discussion on Amendment to the Constitution (Continued).

tion to go into details at this time, but to point out that, with the present arrangement, when the pink ballot is sent out, there is always a strong effort, on the part of the friends of the candidate, to secure favorable action, upon the mere statement of their belief that the candidate is worthy. That has the effect of making the pink ballot entirely ineffectual, and there is no other reason that I can see—if you admit that the pink ballot is, to that extent, valueless—for keeping the election of members in the hands of the members of the Society, as at present.

On the other hand, the opportunity which the Board has of arriving at an accurate estimate of the candidate's character and abilities is so very much greater that it seems to me there is no choice in the matter, and I hope that the amendment will pass

MR. RICKETTS.—Mr. Chairman, Mr. Crowell has stated one view of the question. The other view is this: That a great many members of the Society will not write or give their opinions of the candidates to the Board of Direction, partly because they would be unable, perhaps, to prove definitely their opinions of the man, and, secondly, because they are afraid that members of the Board of Direction would give to the candidates information which had been presented to the Board of Direction.

Now, gentlemen, that thing occurs. Within my knowledge, there has been, within the last two years, a man presented for membership in this Society who was unfit for the position. He was first sent out by the Board of Direction to be voted upon, and was blackballed. He was then sent out again on a pink ballot, and was defeated. He was not a fit member of the Society. He would have been elected, if the election had been in the hands of the Board. They sent it out twice, and the members would not receive him.

Now, that is the other side of that question. And I also know, of my own knowledge, that members of the Board have given information to candidates for membership in this Society—information which they had no right to give. Now, that is the other side of this question. I do not mean to cast any reflections on the Board of Direction of this Society, as a whole. I have been a member of the Board, and I am proud of it, and I do not believe there are any better men in any profession who could be collected together than the members of the Board of Direction of this Society; but I do not believe they give often sufficient consideration, as a Board, to the question; and I do not believe that a man in California, if a pink ballot is sent to him, will give very much more consideration to it than he does at present. I think it is a perfectly safe proposition to leave that matter in the hands of the members of the Society as a whole. (Applause.)

MR. O'ROURKE.—Mr. Chairman, I have been a member of the

Society for nineteen years, and I have just completed a term as a Director. During my term in the Board, when Professor Ricketts was there, I nearly always had the pleasure of being on the same side with him, and I am sorry to see that, having left the Board, he does not continue on the right side of the question.

THE PRESIDENT.—I am informed that it is twelve o'clock, and this is the hour at which the ballot is closed and counted by the tellers.

MR. O'ROURKE.—The speaker's objection seems to be largely due to the fact that the Board of Direction is a fallible body, and that, to some extent, the door is ajar, and now and then information will get out. Well, that may be true; I don't know but what it has gotten out. I can only say that, in regard to the general practice, everything that goes to the Board remains there and never gets beyond. It may be that there are individual instances where that has occurred; that will happen anywhere, and when we can get enough sense together to make a Board of Direction that is infallible and all-wise, then the Professor's idea probably will be reached in regard to what a Board ought to be ; but as long as we cannot get any further than to select from among the body of the American Society of Civil Engineers the best men that are found in it, and make them the Board of Direction, we have got to put up with whatever difficulties may arise from the fact that they are not absolutely perfect.

Now, to get to the regular question: We are not discussing something that is proposed by the American Society of Civil Engineers as a new policy of the Society and a new way of electing its membership, and of being democratic or not being democratic—get away from that idea of democracy which seems to be so popular with some, and with all of us, I hope—but the only thing is we have got to find out how democratic we are. There is no body, of the description of this Society, which asks the general membership to elect its members.

This Society is probably six times larger than it was when I came into it, and the difficulty at that time was that the members were unable to vote intelligently, and that a few would get together, and, from prejudice, or for some other reason, shut out a man who was absolutely worthy. In spite of everything, the Society has grown, so that to-day, not to be a member of the Society, or to be rejected by the Society, by seven unknown voters out of two thousand, who may or may not be acting right, is a stigma; and the reason why people are rejected, very often, is not that they are unworthy, but simply because there are certain people who do not like them; and the more a man is known, while there are more people who like him, no matter how many may like him, they do not make any difference if there are seven who do not like him, however unworthy their motives, or however worthy, if you will, the other two thousand may be, their approval is of no value whatever.

Discussion on Amendment to the Constitution (Continued).

A MEMBER.—You would not get in now.

MR. O'ROURKE.—No, I would not have the least chance. One of the things that I would like to call attention to, in this amendment, is that it is a letter-ballot of the whole Board, and that three votes against any member reject. Now, that lets out all this thing about, "if the Board of Directors had the voice when this unworthy person was turned down in the pink ballot, he would have got in." It does not follow. There might have been three men on that Board who had sense enough to turn down a man asking to come in. That is not asking too much from this fallible Board which is not perfect. We may get three just men there. Who can tell?

What can be more ridiculous, Mr. Chairman, and Gentlemen, than to stand here and say that it is a democratic method that we have now, and that it ought to be kept up in spite of the fact that the experience of every other body, and our own experience, proves that it is wrong. Who votes and has a voice in favor of anybody? No, you can go to the Board of Direction with your troubles, if you have them, in regard to candidates, and the Board will carefully consider whether your troubles are real or not. You can go to your six bosom friends and say you do not like somebody, and he is rejected; and the Society stands helplessly by and sees him shut out. You can send out your pink ballots, and what do you get? You get ten or fifteen people who vote against every pink ballot, and then you get the great body voting on the pink ballot when they don't vote on the white ballot, and they don't vote on the pink ballot unless a special effort is made to bring out the vote.

I remember when the discussion was had, about ten years ago, on this pink ballot. It was supposed that when a wrong was done, everybody would be eager to right it. It has come to be so that not one-tenth of the members vote now for anyone; and the pink ballots don't have anything to do with it. They say: "We don't know." The result is that unless efforts are made to bring out the votes, less than 10% of the body votes, and 10% of that rejects. So, after all, with the pink ballot, unless you make an effort, 1% is a matter of rejection.

This thing of mistrusting your Board, and to have that mistrust expressed by a man who himself has been a member of the Board, and knows the absolute slavery of the membership of being a member of the Committee on Admissions—I never saw anything like it, gentlemen. I have never seen anything like the way in which the letters are weighed, and the evidence is taken against anybody. Unless there is the strongest appearance of injustice, and unfairness, and want of truth, in the objections that are raised against a man, the policy of that Committee on Admissions—and I have seen that Committee changed through three years—its policy is always to give the Society the benefit of the doubt against a man. In other words, the Society will keep every one out who cannot prove his title clear, as far as the Board of Direction is concerned. How is it with the outside parties? The people who waste two cents on a white ballot that does not contain a blackball are simply *nil;* and most of them know it.

Now, take any body: Does the Institution of Civil Engineers elect its members through the general body? Do any of the large clubs do it? Do any of the small clubs, even, do it, without making trouble for themselves?

The only way you can consider a man justly, in view of the rights that every engineer professionally qualified has to membership in the Society, whether we like him or not, if he is worthy otherwise, that can be protected by the Board of Direction, and it cannot be protected by putting it into the power of any seven—sellers of material, who, to get an order, any old thing at all does for an excuse to keep a man out, so long as they don't have to stand behind it, and I say seven will answer. I say it is the opposite of democracy; it is the opportunity for unfairness, and it is the opportunity for sneakery. (Applause.)

Mr. Green.—Mr. President, may I ask how the Board of Direction determines its action as to the sending out of either the white or the pink ballot. Isn't it done by a majority of the Board, the majority action of the Board? How many votes in the Board are sufficient to prevent the sending out of a pink ballot, or what is the action?

The Secretary.—It depends upon the number of members present at a meeting.

Mr. Green.—And the majority of those?

The Secretary.—The majority of those. I might say that the difference, if you will allow me a minute, the difference between the action of the Board under this proposed amendment, as I understand it, and the present action of the Board, in the case of applicants for membership, is that the action is taken at a meeting now where five members constitute a quorum, and by a majority; whereas, under the amendment, this is by a letter-ballot of the whole body, as I understand the amendment.

Mr. Green.—I am asking how the Board now decides ballots; I think it is done by a majority of the Board.

The Secretary.—Not a majority of the Board, but a majority of those present.

Mr. Green.—By a majority of those present. Then I would say to Professor Ricketts that it might be very likely that the Board, in sending out either the white or the pink ballot, may have voted unanimously on it, and that if a minority, or at least a sufficient minority in that Board, which, under the proposed amendment to the amendment, say, three votes, had existed, that white ballot would not have gone out in the first place, and probably the pink ballot would.

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The point I make is that, under the proposed amendment to the amendment, a small number of negative votes in the Board will defeat any candidate. That is not possible now. A small number of votes, under this proposition, would defeat any candidate, would it not?

THE SECRETARY.—Yes, sir.

MR. GREEN.—That would be a minority of the Board, if seven members were present. I was a member of the Committee, last year, which reported against the proposed amendment of this kind. I was the one minority member. It would, perhaps, be interesting for the Society to know that that Committee never held a personal meeting. There was but one other member upon the Committee with whom I was personally acquainted. The way we came to make the report was through a very little correspondence, and I did feel that some of my colleagues might not have had the opportunity to familiarize themselves with this question, as they would have had if we had got together and talked it over.

I believe that this proposed amendment is a most excellent thing, on general principles. Both Mr. Prout and the proposer of the amendment have stated my views of the thing very fairly. It is not a very important question, as far as the expense is concerned, but it seems to me that the Board of Direction has practically and entirely the whole thing in its own hands now, and when the majority of that Board decides to send out a letter-ballot, let it go out, and the members of the Society vote on it with what little light they have, which is very little, usually; and when they decide to send out the pink ballot, it is the same way; they have come to the best conclusion they can, by the majority, and then they have to throw the whole thing over to the Society to be acted upon with but very little knowledge, and very few votes come in. It seems to me to be a very clumsy arrangement, and that it would simplify matters very much, and be much to the advantage of the Society if the Board should attend to the whole matter. It would feel the responsibility more keenly. It can act upon the nominations for membership most intelligently, and it will not be obliged to throw anything upon the Society when unable to conclude the matter in a Board meeting unanimously.

GEORGE HILL, M. Am. Soc. C. E.—Mr. Chairman, there has been one criticism made which, in my experience, is not well founded. I know that, in my own experience, in obtaining admission to the Society, opposition was met which never dared show its head, and that opposition was kept up among the membership. It was simply a matter of personal prejudice, and was finally overcome. I have had other members of the Society request me to vote against members for admission, for reasons which I am very sure those men would not put on paper, and sign with their own names and submit to the Board of Direction; that is to say, for purely personal reasons in no way connected either with the personal fitness of the candidate to be a member of the Society, or with his professional qualifications.

The Board of Direction will occupy the position of a jury, and will waive all good reasons against the promotion or the admission of a candidate. They are best fitted to perform that function, because membership in this Society is not and should not be gauged by the man's personal acceptability to the various members of the Society, but by his professional qualifications, and his personal cleanliness. This is not a social club, where those who are in it are to determine upon the availability of those who are to come in, according to their personal acceptability, but it is a Society, as has been stated, where the only qualifications are personal cleanliness and professional standing, and for that reason the personal element ought to be eliminated as far as possible.

This proposed amendment is nothing more than the logical development of the method of admitting members to the Society, which has been a matter of slow growth, year by year, modified from time to time, in order to meet the conditions as they arise. It has now reached the point where it should be the belief of every thinking member of the Society that the change is an absolute necessity in order to secure the best work of the Society for itself.

In regard to the action by the Board on the application of candidates, I know, of my own knowledge, that the Board does give consideration to the voice of the members. I know of a case where an applicant whose name was sent out on the blue list never got any further. What the action of the Board was, I don't know. I do know that I wrote out what I thought of that candidate, signing my name to it, and sent it to the Board, and I know that the name did not go out to the voters. Whether that was backed up by anybody else or not, I don't know. My objection to that man was simply on his professional qualifications.

At 12.15 P. M. Past-President J. James R. Croes took the chair.

ROBERT MOORE, President, Am. Soc. C. E.—Mr. Chairman, I cannot let a matter of this importance pass without having another proposition which has been made, in this regard, brought at least to the attention of the meeting. The matter itself is one of the very greatest importance. The method of selecting our membership is certainly one that cannot be exceeded in importance by any subject that can be brought before this body.

The present method, while, in the main, it has worked satisfactorily, I think, has not worked satisfactorily in all cases. There have been, undoubtedly, malicious and unjustifiable exclusions from the Society. I have not the experience that many of those who have served practically upon the Committee of Admissions have had, but I know that this is the fact. Now, the remedy for that, which is suggested

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by this amendment to the amendment, is to revolutionize completely the former plan, and to throw the whole matter into the power of the Board of Direction.

Now, there is another suggestion which, I think, was made to this meeting a year ago, which, so far as I know, was first brought before a meeting of the local members of the American Society of Civil Engineers at St. Louis, which was to solve the difficulty, not by throwing the election into the Board of Direction, but by increasing the number of negative votes required. Now, in a membership as large as ours, I think it may be admitted that seven votes, which is but a fraction of 1% of the total number of Corporate Members, is too small a number, and that it needs to be remedied in some way, and the suggestion at that time—and I think it is a suggestion which has been canvassed in the Board of Direction—was that the number be increased to approximately 1% of the total number of Corporate Members, which, at the present time, would be twenty or twenty-one.

Now, I think a great many members, perhaps not as well informed as some others, would prefer a method of that kind to one which is so entirely revolutionary as the one which has been suggested by Mr. O'Rourke's amendment, and I think that this plan ought to be brought to the attention of this meeting. This matter was considered by a Committee of the Board of Direction, I believe not approved by the Board of Direction, but a report was made which substantially embodies that idea, and, personally, it seems to me that it would be probably the best action to take at the present time. It seems to me that it would probably cure nine-tenths, if not the whole, of the malicious blackballing, which is now complained of, and which is sought to be remedied, and if so, it would, I think, be a safer remedy, and one which would greatly relieve the Board of Direction of the responsibility, which they certainly are not anxious to take, of bearing the whole burden of the election of members to the Society.

The gist of this proposed other plan is contained in this clause:

> "The ballots shall be letter-ballots, in a form to be prescribed by the Board of Direction. They shall be mailed to each Corporate Member whose address is known, and shall state the date on which the ballot is to be canvassed, and which shall be not less than twenty days after the issue of the ballot. Twenty or more negative votes shall exclude from election."

If that twenty were made 1% of the Corporate Members, as at the time being, or at the time of the last list of membership, I think that it would go a long way toward curing the trouble which is now sought to be remedied.

Mr. O'Rourke.—Mr. Chairman, in relation to what Mr. Moore has just read, the report of that committee was made to the Board of Direction, and the reasons given by the committee were much the same as those given now by Mr. Moore for making that report. It was not that they considered it the best action, but they considered it the action that would be most likely to meet the difficulty, and at the same time meet with the approval of the general body and of this meeting. In other words, they believed that what my amendment to the amendment embodies was the best. It was passed upon by the Board, and approved by the Board as a substitute for this action of their own committee, and, as I am no longer a member of the Board, it was thought that it would be perfect good taste in having it presented by me, not as being the action of the Board, but it was their belief that it was the proper thing to do.

Mr. Moore, himself, states that it is not the best thing to do, this election of members by an uninformed body, as it is absolutely impossible to inform that body as to the qualifications of anybody, and right was considered as something; but they had this belief, which I do not believe, even though this meeting votes against this amendment.

My belief is that the Society wants to do what is right, even when it is radical, and the right thing to do is what every other Society does, elect your members by a body which is qualified to do it, by the knowledge which is brought to them, and by the knowledge which they themselves possess, and that is why this suggestion cannot be considered ; for, of course, we cannot consider an amendment to an amendment, because you have either to accept or reject that amendment to the original amendment proposed as it is offered, and if you don't want to do anything radical, and rather prefer to do something which is half right and partly radical, why it is up to you to do it that way. (Applause.)

C. F. Allen, M. Am. Soc. C. E.—It seems to me that the gentleman who has proposed the amendment to the amendment has come near proving too much. He rather protests that the Board of Direction ought to be trusted. Why doesn't he protest that the Society ought to be trusted? Why can't you trust the Society as well as trust the Board of Direction?

I believe you can, but the objection is urged that there are some bad members in the Society. How did they get there? They went by the Board of Direction, if they got there at all.

Now, there is no way of doing this thing right. There is no way of handling it, so far as I can see, in which the action will be satisfactory. If you entrust it to the Board of Direction, the work will not be efficiently done. Men will go by who ought not to go by. If you entrust it to the Society, men will be rejected who ought not to be rejected. There is no escape from those propositions, it seems to me.

Not many years ago, in talking upon this particular matter, I talked with a member of the Society who had been in the Board of Direction, the Chairman of the Board of Direction—a man in high

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esteem in the Society—and his criticism was that it was undesirable that the matter should be thrown into the Board of Direction; that, in his experience, the action of the Board of Direction at times had been such that it was unwise to put the whole matter into its hands. It certainly is true that cases, as he suggested, had gone by, had gone through the Board of Direction, that ought not to. Certainly, members have been at first rejected, and have been again rejected, when they ought not to have been rejected.

We then, substantially, meet the proposition, what shall we do? Shall we take the chance of shutting out a good man, or shall we take the chance of letting in a bad man? I believe that we want to resist the chance of taking in the bad man. I believe that it is a mistake, on the whole, to take the affair out of the hands of the members.

It is perfectly true, as one of the previous speakers has stated, that I, or other members, may be entirely satisfied, but it may be absolutely impossible for us to prove, that he is an undesirable member, and yet our instincts are so clear and right, upon the best motives, upon the best qualifications for membership, that the ballots ought to be cast against the candidate.

It is said that seven bad members may cause the rejection of a good candidate. Why can't five members, who are the only members who know an applicant—five bad members—why can't they put the man into the Society? Where does the Board of Direction get its information, except from those five men?

There are a good many sides to it, I believe, and we want to hesitate before we take the power from the hands of the individual members, who, locally, are able oftentimes to have facts, which are the proper thing as the basis of admission—some of the people, locally, may have facts that do not really come to the Board of Direction. The Board of Direction has a good deal to do; they are busy men; they are not able always to get at the facts definitely. (Applause.)

J. N. **Greene**, M. Am. Soc. C. E.—Mr. Chairman, I want to ask Mr. O'Rourke, as a matter of information, how the Board of Direction gets information and knowledge as to candidates for this Society, and gets information which is definite enough, and positive enough, to settle this question whether a man shall be admitted or not?

Now, I cannot see, from the debate, as far as it has gone, any plan, and I ask Mr. O'Rourke, in having been a member, what is the *modus operandi* at present, if any, which is taken to find out the qualifications of a candidate when he asks to be admitted to this Society?

Mr. O'Rourke.—Mr. Chairman, the *modus operandi*, so to speak, is to send out a blue list, notifying the whole body of the Society of the application of the person for membership, and requesting confidential information. That is done to-day. That information goes to the Committee on Admissions, and I have known cases where four men, and often more, were turned down by the Committee on Admissions at a single meeting, due to the evidence that was received as to the unworthiness of the applicant; and, further, if information is received against anybody which does not bear the stamp of truth on it, the Committee on Admissions, though they are busy men, go further into the matter. The name is put back, and put back, and put back, until they are fully satisfied. They take cognizance of the right of the good man to come in, as well as the right of the Society to exclude the bad, and that is something that cannot be done by the body at large, and that is something that it does not do to-day. It does not vote; it does not consider. Only those who have anything to say against anybody—and their saying is merely a black mark—those are the ones who really communicate anything to the election, and, further, Mr. Chairman, that is considered afterward by the Board.

Now, in the discussion, the point seems to be missed that, while to-day a majority of those present, voting in favor of a thing, will carry, though they may not be a majority of the whole Board, this amendment provides that all the information—of course, that is in the Board itself, to give information to the members—the Board as a whole will have to vote on every name that is brought up, and three members of the Board will be sufficient to exclude, voting in the negative.

MR. GREENE.—I was quite aware of the blue list and of the manner of sending it out, but what I want to get at is, if there is anything in the Board of Direction, aside from what Mr. O'Rourke has just stated, that would enable the Board to decide this question any more accurately or justly than it is being decided in this, it seems to me, too loose way we have now. Is there any other?

MR. O'ROURKE.—They take whatever evidence they get. It is up to the members to furnish the Board with objections, and that is done all the time. It is a great mistake to think that every name that goes out on the blue list comes out on the white list afterward—it is far from that.

MR. GREENE.—It seems to me to be evident to every member of the Society that it is a very embarrassing thing, and a very difficult thing, for him to take a blue list, about which he may know something, or little, or much, or, perhaps, not anything, and he hesitates before he discriminates against a man and sends information to the Board, unless he has positive knowledge. It would not be fair for him to do it unless he had.

Now, it seems to me, the difficulty in this matter is that this thing is not concentrated in any workable, proper manner. It seems to me that there ought to be a committee of this Board of Direction whose business it shall be, confidentially, to ascertain the facts, and whose business it shall be to keep everything of that kind that they get into

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their possession positively and absolutely to themselves, and not as the gentleman over there has described, that he has known of cases where the Directors have given out information by which men were rejected, which is a very unjust thing, as we all agree.

Now, this matter of getting into this Society as a member should not be looked upon as so small a thing as not to attract anybody's attention. It is a great thing to be a member of this Society, if men would only look at it that way.

Now, what is our position in this matter? We are entrusted, more than any other body of men on this continent, with the expenditure of capital for the improvement of the public works of this country and the country's general good, and we are called upon, and should be held right up to the mark, that we make good that expectation of the public, because the man who takes a position as an engineer and disburses millions of money should be, beyond any question, rock-bound in his integrity, and naturally he should be well advised, well educated by experience, and show his ability to cope with the subjects that may come before him.

I make the statement here, and I believe it is true, that, for two reasons, more money has been wasted on the public works of this country in the last fifty years than it would take to pay the public debt of this country when our Civil War closed. What are those two reasons? They are very lucid, and very short, and very nubby. First, the brains and ability and knowledge of the business that the man who has the matter in hand, whether he is able to cope with it and do it properly, and the next is, whether he has got such integrity at rock-bottom that he will do justice between the parties, let what will come.

. Now, we know that men have got into such positions in this country; for instance, this matter in Savannah, a few years ago, by a United States officer, educated, I believe, at West Point, and now serving time, in a western penitentiary, for stealing. There was a man, educated at his country's expense, and it seems to me the only mistake that was made in that man's case was that he had not gone to State's Prison before he went to West Point; then he could not have done this mischief.

There ought to be some way in which this Society can exact from the candidates who want to come into it facts and information sufficient to give the Board of Direction—or whoever is left to decide this question of who shall come in and who shall stay out—absolute knowledge enough so that they will feel that, conscientiously, they are safe in letting a man in, or they are acting exactly as honestly in saying that he cannot come in.

It seems to me, Mr. Chairman, that something of that kind should be done in the Board of Direction, if this amendment passes. Now, what is everybody's business is nobody's business, is an old saw—

older than any of us here—and if this amendment be passed, and the Board then appoints a sub-committee whose duty it shall be to do that, and make it their business to see to it, it seems to me that this question, and this trouble, will be largely removed, and very easily; but I do not see how it ever can be done, in the *modus* under which we are now proceeding.

MR. RICKETTS.—Mr. Chairman, I would like to ask a question. It is assumed that members of the Board of Direction who may reside in California are to vote intelligently on each application. Suppose a member shows a letter to the Board in which he says that he knows or believes that a certain applicant is a blackguard and a rascal, do I understand that, under this amendment, the Board intends to print that, and send it out through the United States mails to the different members of the Board throughout the United States? And, if they don't do that, how can the various members of the Board, distributed throughout the United States, vote intelligently in any case?

MR. O'ROURKE.—The best answer to that, Mr. Chairman, is to state what is the practice at present in the Board. All such communications, and all preliminary considerations of an applicant, are considered by a committee similar to the committee that Mr. Greene has spoken of, who take all these facts into consideration, and when the name comes before the Board they recommend either that he be accepted or rejected. Usually, the rejection follows in any case. I have never known of a name to go by that committee, so that, even if the Board was present, and even if they had this stuff piled up there in a basket before them, they would never even ask for it, or ask to see it, if the Committee's report on the man who is not favored by them is presented; I have never known of a case that it was not so considered by the action of the Board. There may be a few instances, of course, but I am probably proceeding too far; but I am talking about the general practice. The confidence of the Board in this Committee is so great that they rarely go beyond that, if there is any reason to believe that he is not worthy. No matter what would be the proceeding under this amendment, I would say that whenever any real occasion arose for communicating to everybody on the Board, means will be found to do it. I think we can trust the Board for that.

There is no doubt about it that the only way you can sift a thing like that is to sift it through a committee, and once your committee has given its conclusions on the matter, if you want to go behind the committee, then it is time to go about it.

MR. RICKETTS.—In other words, this local committee, which must necessarily be a local committee, is to determine who shall be members and who shall not be members of the Society. (Applause.)

E. P. NORTH, M. Am. Soc. C. E.—Mr. President, I listened with a great deal of pleasure to Mr. O'Rourke's description of the proceedings before the Committee on Admissions. It does not quite agree with a

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little bit of experience I had, I think before Mr. Ricketts was a member of the Board.

I saw in the blue list the name of an applicant who, I thought, was unfit for membership. I wrote to the Board of Direction that, before his name was passed to ballot, I might be further communicated with, as I would like to make a personal communication. The next month the name came out on the ballot list. I inquired about the thing, and, while I cannot make any official statement, I think I am justified in mentioning my suspicion that the name was examined, one among over sixty, on a very hot September Tuesday, and the fact was that they did not get to my letter at all, but passed the man among that number, as I take it.

Now, that is an extreme case, I am perfectly willing to admit, and I wish to urge that it is an extreme case; but I wish to say to the members of this Society that if this proposed change in the Constitution is made, one provision against the admission of unworthy members is swept away. It does not make much difference to the older men in the profession what reputation a young man has, but a young man who is looking for a place, and says he is a member of the American Society of Civil Engineers, is very severely handicapped by the knowledge that another member of the Society is unworthy of the name, either of a civil engineer or a man. (Applause.)

G. F. Swain, M. Am. Soc. C. E.—Mr. Chairman, I am heartily in favor of Mr. O'Rourke's amendment. I hope it will be adopted. I believe in concentrating responsibility, and I do not know of any better place to concentrate responsibility than upon the Board of Direction of this Society. It is the way that every large corporation does business; it is the way that a great many of the large clubs, if not all of them, and many of the professional societies elect members.

I think that we might trust the Society, as Professor Allen suggests, if the Society had information, and if the Society, and every member of the Society, or every seven members of the Society, would act squarely. I do not believe in giving seven members of the Society an opportunity to stab a man in the back for personal reasons. If there are seven members of the Society who think that a man ought not to be admitted, they certainly can bring information enough into the possession of the Board of Direction to enable that Board to form a fair opinion of the justice of their reasons.

I think that it must not be lost sight of that the proposed amendment will change the present mode of procedure of the Board. Five members of the Board now constitute a quorum, I believe, and three, therefore, would enable a meeting of the Board to pass a candidate for ballot. That is the way in which, perhaps, some unworthy men have become elected, have been passed to ballot, as Professor Allen states.

The mode of procedure proposed by Mr. O'Rourke would require the Board of Direction to vote by letter-ballot. I do not see that there is any difficulty, as Mr. Ricketts seems to think, in getting information to the various members of the Board in regard to the unworthiness of certain candidates. If a member of this Society knows that a candidate is a blackguard, and writes to the Board, giving his information, it is just as easy to write to the various members of the Board and give them the facts. There is no difficulty about that.

I believe in concentrating responsibility in the Board, and I think very likely the Board would modify, to some extent, its procedure. Responsibility always makes a man more careful. The Board is very careful now; I know from experience how much care is taken by the Board on the admission of candidates, and how carefully they consider every candidate. I cannot conceive at the present time of any letter from Mr. North not having been given great consideration. I don't know how it was. It was many years ago, perhaps ; but I know how it is at present, and I, therefore, am strongly in favor of the amendment of Mr. O'Rourke. (Applause.)

Mr. North.—I would like to ask, before the Professor sits down, definitely, if it is much better to allow three or five men to stab a man in the back than seven ? It really comes to the Board of Direction, a smaller number of Directors than is required now, preventing absolutely a man's election. The Directors are taken from the main body of the Society, and I do not understand that they are much more reliable than those of us who are not Directors, and are fully as able to stab a man, I take it (laughter).

Mr. Green.—It is a great deal safer for the Society to reject a good man this year, if he can be admitted later, when more information about him can be secured than could be had in the first place, than it is to let an unqualified man come in. If there is anything at all of value to the members, or anything at all in membership in the Society, it should be the standing of its members as good engineers, and if an unworthy, unqualified man gets in, he is in there to stick, and you cannot get him out, but you can very easily put in a qualified man who has been passed over the first year for lack of information, or because someone wishes to stab him in the back, and elect him after a while.

I think the Board of Direction can be entirely trusted in this business, and if five members, only, constitute a quorum before the letter-ballot was sent out to all the members to vote upon the candidate, and it happens to be found that three out of those five vote against him on the spot because there is some question about the candidate, it is not necessary to send out the ballots to all the membership. It seems to me that we are straining at a gnat and swallowing a camel. Mr. Rickett's case has been entirely taken care of and disposed of in

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the particular way that it came up, if the minority who may have voted against the candidate at that time had been three in number.

I believe, as do many others, in holding up to a very high standard the candidates for membership in the Society. I think that too many men get in now who are lacking in the qualifications that they ought to have; they might wait a little while. A good many young fellows on reaching the age of thirty apply for membership and try to get in, but it is better for the Society that the Board of Direction should scrutinize these applications with considerable care, and, in my experience, it is safer for them to reject them, if necessary; and I say that it is a great deal better for the Society to reject, once in a while, a very well qualified man, a desirable man, than it is to make a mistake and elect an unqualified man.

(The President resumed the chair.)

T. S. WHITE, M. Am. Soc. C. E.—I would like to ask the President one question in regard to the amendment that he spoke of and suggested a little while ago, as to increasing the number necessary to exclude. Have there ever been twenty negative votes cast against any member?

G. I. BAILEY, M. Am. Soc. C. E.—Mr. President, in regard to this amendment to the amendment proposed by Mr. O'Rourke, I wish to say that I am opposed to it, and that several members of this Society, who do not live in New York, and whose associations in the Society are confined to receiving its publications, and the communications mailed from the Secretary's office, and an occasional blue list and ballots to members, are opposed to it.

If abuses have been made in the election of members to this Society, I think the thing to do is to get at those abuses and stop them. If you cannot expect the members to vote intelligently and properly for admittance of candidates to their own membership, I do not see how you can cure that evil by allowing those same members to vote for members of the Board of Direction, and then shifting that responsibility over to that Board.

I believe the suggestion made by yourself, or by some one before, that if a committee of seven in the Society may keep out members, then that number should be enlarged, and, as you say, a percentage of the whole membership of the Society, or else a percentage of the whole number of votes cast, should exclude. The pink ballot does correct that evil of seven, as has been demonstrated a number of times in the last few years, but for these up-country members, of whom I am one, we like to have something to say, occasionally, in regard to the Society, and feel perhaps like the Americans of a hundred and thirty years ago, when they had the little tea-party up around Boston. We are all taxed for the Society, we pay our dues, and we want something to say for it, and if we are not competent to pass upon our own members, I do not believe in appointing some nurse to do it for us; give us all a chance. (Cries of Question.)

The President.—The question is called for. The question is upon the amendment to the amendment offered by Mr. O'Rourke, which, I think, it is not necessary to read. Those who are in favor of the adoption of the amendment to the amendment proposed by Mr. O'Rourke will signify by saying aye; contrary, no.

The Chair is unable to decide.

G. S. Morison, Past-President, Am. Soc. C. E.—Before any further vote is taken, Mr. President, I should like to know what this amendment to the amendment is?

The President.—Well, it is an amendment which, in effect, throws the election of members wholly into the Board of Direction.

Mr. Morison.—May I ask to have that read?

The President.—The reading of that amendment is asked for, and I will ask the Secretary to read it.

(The Secretary read the amendment to the amendment.)

The President.—Having heard the amendment to the amendment, proposed by Mr. O'Rourke, all those who are in favor of it will signify by rising and standing until counted.

(The Secretary announced sixty-eight votes.)

Mr. Allen.—I rise to a point of order. I would like to know what the situation is as to those men who are standing, not from their seats, but behind the seats in the rear of the room; are those members properly counted in the room or not?

The Secretary.—I counted everybody standing in the room; not outside of the room.

The President.—Those who are opposed to the amendment will rise.

(The Secretary announced eighty-eight votes.)

The President.—The amendment is lost. The question now recurs upon the amendment as it was heretofore read, the amendment which you have received in print.

The Secretary.—Allow me to say, Mr. President, that this meeting can do nothing with that amendment except to amend it. Unless that proposed amendment is amended by this meeting, under the Constitution, it goes to letter-ballot of the Society.

The President.—The Secretary is correct. The proposed amendment having failed, the original amendment goes to the Society for letter-ballot. If there is no amendment offered to this, it will go out in the form in which it is. This is simply to the effect that the Board of Direction may classify; it has no bearing upon the number of negative votes that may be necessary to exclude.

Mr. Knap.—I wish to ask for information, now that that amendment has been voted down, is it in order to present another amendment?

Discussion on Amendment to the Constitution (Continued).

THE PRESIDENT.—In the nature of an amendment to this; yes, sir.

MR. KNAP.—I am sorry I have not got it written down, but I would like to make an amendment to the amendment to this effect, that, in order to exclude, the number of negative votes should be 1% of the Corporate Membership at the last Annual Meeting, or at the time of the last Annual Report; 1%, which would be, as the President has stated before, about twenty at the present time. Instead of seven, I wish to substitute the number twenty.

THE PRESIDENT.—That is, you wish to substitute 1 per cent.

MR. KNAP.—Twenty, or 1%, which will be at this time about twenty.

MR. SWAIN.—I second the motion.

THE PRESIDENT.—The amendment is seconded and is now before you, which amends Section 4 of Article III, making it 1% of the Corporate Membership.

THE SECRETARY.—As of the 1st of January of each year?

THE PRESIDENT.—Yes; necessary to exclude.

MR. KNAP.—I would state, in addition to that, that when the number seven was decided upon, as I understand it, there were about seven hundred members in the Society, and that was really about 1%, but twenty is now practically the same percentage of the Society as seven was at that time.

THE PRESIDENT.—The amendment is now before you for discussion, gentlemen.

ALLEN HAZEN, M. Am. Soc. C. E.—It seems to me that there may be a great many men proposed for membership of whom there would not be twenty men who know well enough about their position and standing to pass intelligently upon this point, and in that respect twenty to-day may be a much more liberal allowance than seven, which was 1% at the time it was adopted, if that were the case. And I question if twenty is not a larger number than we can afford to give at the present time, even if seven is too small. I am not one of those who feel that to be defeated by seven votes is anything to be ashamed of, or to feel unduly. There is a satisfaction in having gone through the pink ballot and feeling that the great majority of the members of the Society are behind you.

MR. WHITE.—Just in regard to that point that Mr. Hazen has made, the question arises again as to how many votes were ever cast against a man, and whether it is possible that anybody would ever be excluded if it required twenty votes to exclude him as a member.

THE SECRETARY.—There have been twenty votes cast against a candidate, and there has also been one voter who has voted against all the candidates on a ballot list, on which I think there were forty-six.

MR. HILL.—As I understand it, Mr. President, 1% of the Corporate Membership, according to the list as handed out to-day, is only about seventeen voters, and seventeen votes are considerably less than twenty. It seems to me that the real effect of this proposed amendment is to carry into effect by indirection the amendment which has just been voted down, because it seems to me that it would rarely happen that such a number of adverse votes would be cast. It seems to me that that is a very exceptional number. In this particular case the men who know objectionable characteristics on the part of the candidate, in order to make that objection effective, must vote through the Board of Direction, so that the effect will be, if we feel that a candidate is objectionable, we must go to the Board and stop him there, feeling certain that it will be difficult to get the requisite number of voters.

(Calls for the question.)

F. W. Hodgdon, M. Am. Soc. C. E.—Mr. Chairman, this question seems to be entirely out of order. The question of the number of negative votes which will come up is an entirely new question. It is not an amendment to the amendment which is to go before the Society at the present time. That simply refers to the application of the applicant. This is the method of election of the applicant, and should come in as an entirely new amendment and be presented to the meeting, and be presented to the Society for discussion. (Applause.)

(Calls for the question.)

Mr. Croes.—I think, Mr. President, that this is entirely germane to the amendment. This resolution making the change in the Constitution is offered, and this changes two or three words of it, and that is all.

Mr. Hodgdon.—Not germane to the subject, but to the other amendment.

Mr. Croes.—It changes two or three words in that; it makes it twenty instead of seven, that is all.

Mr. Hodgdon.—That question is not up in the amendment.

Mr. Croes.—The amendment is this amendment to the Constitution, and this is an amendment to that amendment, and it is perfectly proper.

(Calls for the Question.)

The President.—That raises a question which it is a little difficult for me to decide off-hand. Both are amendments to Article III, though not to the same section of Article III.

The Secretary.—The language of the Constitution is, that an amendment may be amended in any manner pertinent to the original amendment.

Mr. Hodgdon.—What section is it that it is proposed to be amended?

The President.—It is proposed in the original to amend Section 3, Article III.

Discussion on Amendment to the Constitution (Continued).

Mr. Hodgdon.—In relation to the proposed amendment to that, where we had the proposed amendment of Mr. O'Rourke, that came up, because it was proposed to amend Sections 2 and 3 of Article III; but the amendment proposed by Mr. Knap amends Section 4 of Article III. I just raise the point of order that it is not germane.

The President.—I think I shall have to decide that it is not in order.

Resolution in reference to the late Abram S. Hewitt.

Mr. Morison.— Mr. President, is there any other business to come immediately before the meeting? If not, I would like to offer a resolution. It has not been the custom of this Society to pass special resolutions in relation to special men, but it seems to me that the coincidence of this meeting in connection with the history of this city, and of the country, for a great many years, calls for some special action now.

Some of us were late in coming to this meeting to-day, and the reason for that was because we cared more about rendering the little respect we could to one whose memory the whole engineering profession has honored than for attending to the business here this morning, important though it be.

At precisely the same hour for which this meeting was called the last services were held over the man who, for a long time, we have looked upon as New York's first citizen, and who, if any man outside of the profession has ever done much for engineers, he has certainly done it. My own personal acquaintance with him began about thirty years ago, and for twenty years I have felt that, if there was any subject upon which I needed especially sound advice and help, he was the man for me to go to. I think there are many of us who have felt in that same way.

I therefore offer the following resolution:

Resolved, That the members of the American Society of Civil Engineers, assembled in their Annual Meeting at the hour when the last sacred rites were performed over the mortal remains of Abram S. Hewitt, desire to place on record a brief recognition of the debt which so many of them individually, and all of them as a profession, owe to him who was for so many years New York's first citizen.

While he always disclaimed being an engineer, he had the mind and spirit which mean more than the actual professional name. While not enrolled among their numbers, his whole life, as a citizen, a manufacturer and an educator, was devoted to those interests which have made the engineering profession possible.

Few cities have had so patriotic a citizen. No profession has had a warmer friend.

(Applause.)

R. W. Hunt. M. Am. Soc. C. E.—I desire the privilege of being a seconder to that resolution, and I think, sir, we all feel it fitting that this Society should pass such a resolution. While Mr. Hewitt was not a member of our own organization, he was a Past-President of a sister national society, and, surely, if ever a man served his country, and served his country in a way that was effective, it was he.

In looking at the progress of the world, the advancement of mankind, and those who have been connected with it, it is difficult to draw lines showing exactly where such a one's influence has extended and ended.

So, with Abram S. Hewitt, we cannot exactly mark out the great industrial advancement of the United States, or the progress, or the better condition of its citizens that was brought up to a certain point by him; but surely no man has lived in his generation who has done more to sweep on that tide. He has given and done the things that were best calculated for the true advancement and the true benefit of his fellow men, and now, sir, God has made the just man perfect. (Applause.)

The President.—Gentlemen, you have heard the resolution offered by Mr. Morison, and so ably seconded by Mr. Hunt. All in favor of its adoption will signify by rising.

It is a unanimous vote.

The Secretary.—I have the report of the tellers.

The President.—If there are no other resolutions to offer——

J. A. Ockerson, M. Am. Soc. C. E.—I would like to offer a resolution.

The President.—Well, that will be in order.

International Congress of Engineering.

Mr. Ockerson.—*Resolved*, That it is the sense of this meeting that the American Society of Civil Engineers should co-operate with the officers of the Louisiana Purchase Exposition Company, in the inauguration of an International Congress of Engineering, to be held in St. Louis, during the Exposition period of 1904, and be it further

Resolved, That the Board of Direction be, and is, hereby, authorized and requested to take such steps as may be necessary to carry out the provisions of the foregoing resolution.

I might say, gentlemen, in this connection, that the Exposition Company is making very generous provisions for the scientific congresses, and, of course, it is important that the American Society of Civil Engineers should take a leading part in the engineering congresses. For my own part, I should be very glad to have the Society make use of my department at the Exposition in any way possible to help this matter along. The use of stenographers, typewriters, and other members of the force is at your service.

The resolution was duly seconded.

The President.—Is there any further discussion upon it? I will ask for the vote. Those in favor of the adoption of the resolution, which you have just heard read, will signify by saying aye; those opposed no.

Carried.

The President.—If there are no further resolutions, the next order of business will be the report of the tellers.

Report of Tellers.

THE SECRETARY. The tellers' report is as follows :

Report of Tellers Appointed to Canvass the Ballot for the Election of Officers at the Annual Meeting, January 21st, 1903.

Mr. Chairman: Your Committee, appointed to canvass the ballot for Officers, reports as follows:

Total number of ballots received		710
Not entitled to vote	1	
Without signature	13	
Voted nominating blank	1	
		15
Counted and found correct		695

For President:

Alfred Noble	691
Edward A. Bond	1
F. W. Cappelen	1
Henry S. Haines	1

For Vice-Presidents:

L. F. G. Bouscaren	684
James D. Schuyler	687
O. F. Nichols	2
Wm. M. Black	1
Addison M. Scott	1
Howard G. Kelley	1
Thomas H. Johnson	1
D. C. Henny	1
W. H. Kennedy	1
W. F. Tye	1

For Treasurer:

Joseph M. Knap	693
Palmer C. Ricketts	1

For Directors:

Alfred Craven	686
Joseph O. Osgood	684
George S. Davison	676
E. C. Lewis	672
Hunter McDonald	679
Elwood Mead	671
C. E. Grunsky	3
J. M. Johnson	2
J. B. Lippincott	2
H. M. Wilson	2

David E. McComb	1
R. C. McCalla	1
Chas. H. Graham	1
B. S. Wathen	1
A. M. Scott	1
J. C. Guild	1
J. A. Ockerson	1
Jos. Ramsey, Jr.	1
Geo. S. Webster	1
Arthur L. Adams	1
D. C. Henny	1
W. H. Kennedy	1
Edward B. Taylor	1
Louis Y. Schermerhorn	1
F. A. Molitor	1
C. L. Harrison	1
D. W. Lum	1
James B. Atkinson	1

Geo. C. Stoddard,
C. D. Pollock,
Tellers.

January 21st, 1903.

Remarks by Past-President Moore.

The President.—Gentlemen, you have heard the report of the tellers, and with this election your present President retires. I cannot do so, however, without expressing to you and to the Society at large my thanks for the compliment which you have paid me in choosing me as your President, and further extending my congratulations to the Society upon the great prosperity which this Fiftieth Anniversary Meeting now witnesses; and when we see what we do see here before us, a large Society gathered in a house of its own, and compare it with the small beginning of the Society fifty years ago, I think we see that there has been planted here a very vigorous plant, and we may be sure that the next fifty years will witness a Society which will be of the utmost importance, not only to this profession, but to the whole country.

I will ask Mr. Morison and Mr. Croes to conduct the new President to the Chair.

President Noble Introduced.

Alfred Noble, President, Am. Soc. C. E.—Gentlemen of the American Society of Civil Engineers: I appreciate very deeply the honor of the election to the Presidency of this Society, and this cordial greeting which you have been good enough to accord me. This Society is the best exponent of the profession of engineering on this hemisphere. Of the four great national societies, it is the one which seeks to embrace in its ranks all branches. Nine times in ten the engineer must stand or fall on the simple issue of the performance of duty. On this issue, I perceive, with some alarm, that I must hazard what I prize most highly, the continuance of the good opinion of my professional brethren. In return for the honor which you have been good enough to bestow on me, I can only promise to regard the responsibilities I am about to assume as commensurate with the honor they imply, and to discharge the duties which I gratefully assume to the best of my power. (Applause.)

Memorial Tree at Mount Vernon.

THE SECRETARY.—Mr. President, I have one letter which I omitted to read, and with your permission I will read it now.

ST. LOUIS, MO., JAN. 19, 1903.

MR. CHARLES WARREN HUNT,
Sec'y. Am. Soc. Civ. Engineers,
New York.

Dear Sir:

I hereby report to the Society that, in pursuance of the resolution passed at the last Annual Convention in Washington, I have had an oak tree planted at Mount Vernon, as a memorial of the visit of the Society in May last.

In the execution of this work, I have had the invaluable assistance of Mr. Gifford Pinchot and Mr. George B. Sudworth of the Bureau of of Forestry and Mr. Harrison H. Dodge, Superintendent of the Mount Vernon Estate, and the thanks of the Society are due to these gentlemen.

Yours very truly,
ROBT. MOORE,
President.

MR. MOORE.—I move that the Secretary be instructed by this meeting to extend the thanks of the Society to these gentlemen whom I have named. They have executed, with great skill and fidelity, this commission which was placed on them, and, I may say, without any cost to the Society. I think that the vote of thanks is due to them.

The motion was duly seconded and carried.

After several announcements by the Secretary as to features of the programme for the meeting, the meeting, on motion duly seconded, was adjourned.

EXCURSIONS AND ENTERTAINMENTS AT THE FIFTIETH ANNUAL MEETING.

Wednesday, January 21st, 1903.—After the business meeting, lunch for about 450 members was served at 1.30 P. M. in the Lounging Room. At 3 P. M. a large party, under the guidance of Alfred Craven, M. Am. Soc. C. E., Division Engineer, visited and inspected the tunnel of the Rapid Transit Railroad, between Sixtieth and Forty-second Streets. The station at Broadway and Sixtieth Street, and various portions of the tunnel were lighted for the occasion. Smaller parties visited other parts of the work, in Harlem, on Park Avenue, at the City Hall, etc., during the afternoon.

At 9 P. M. there was a Reception, with dancing, in the Society House, at which the total attendance was about 375.

Thursday, January 22d, 1903.—At 10 A. M. the steamer *Valley Girl* (kindly furnished for the occasion by John H. Starin, Esq., and General Howard Carroll) with about 400 members and guests, including many ladies, left the Recreation Pier at the foot of East Twenty-fourth Street for an excursion. By invitation of Hon. Gustav Lindenthal, M. Am. Soc. C. E., Commissioner of Bridges, the party visited the site of the Blackwell's Island Bridge (No. 4) and inspected the masonry piers, on Blackwell's Island and at Ravenswood, in course of construction. Lunch was served on the boat while on its way down the river, and a stop was made at Hoboken to inspect the new fire-proof piers which are being constructed by the North German Lloyds Steamship Company. The party was landed at the pier at the foot of West Thirty-fifth Street, New York, at about 5 P. M.

In the evening there was an informal "Smoker" at the Society House, about 400 members and guests being in attendance.

The following list contains the names of 396 members, of various grades, who registered as being in attendance at the Annual Meeting. This list is incomplete, on account of the failure of many members to register, and it does not include the names of any of the guests, of the Society or of individual members:

Abbot, F. W.......New York City
Abbott, E. L......New York City
Aiken, W. A.......Pittsburg, Pa.
Allen, C. A......Worcester, Mass.
Allen, W. A........Maurer, N. J.
Ashbridge, R. I. D. Philadelphia, Pa.
Atkins, H. B......New York City
Auryansen, F.....New York City
Aus, G...........New York City
Bacon, J. W.....Danbury, Conn.
Bailey, G. I.......New York City
Baker, E. B. Morgantown, W. Va.
Barnes, W. T...... Boston, Mass.
Bascom, H. F..... Allentown, Pa.
Basinger, J. G.....New York City
Belden, E. T.. Middletown, Conn.
Belknap, W. E....New York City
Bellinger, L. F...Brooklyn, N. Y.
Belzner, T.........New York City

Bensel, J. A.......New York City
Benton, L. S......New York City
Benzenberg, G. H. Milwaukee, Wis.
Berg, W. G........New York City
Bettes, C. R..Far Rockaway, N. Y.
Beugler, E. J.......Boston, Mass
Bishop, G. H. Middletown, Conn.
Bissell, C. T.... ..New York City
Bissell, H.........Boston, Mass.
Boller, A. P.......New York City
Boller, A. P., Jr....New York City
Bonzano, A.....Philadelphia, Pa.
Booth, W. F......New York City
Bouscaren, G....Cincinnati, Ohio
Bowman, A. L.....New York City
Bramwell, G. W...New York City
Breuchaud, J......New York City
Brinckerhoff, H. W. New York City
Bryson, A...........Reading, Pa.
Buchholz, C. W....New York City
Buck, H. R......Hartford, Conn.
Buck, L. L........New York City
Buck, R. S..... Montreal, Canada
Burdett, F. A.....New York City
Bush, E. W..... Hartford, Conn.
Butts, E. P....Springfield, Mass.

Carney, E. J.......New York City
Carr, A............New York City
Carter, A. E .....New York City
Carter, Shirley......Norfolk, Va.
Cattell, W. A......New York City
Chambers, R. H....New York City
Chase, F. L....... New York City
Chester, J. N......Pittsburg, Pa.
Christian, G. L....New York City
Christie, G. B.......Chicago, Ill.
Clapp, O. F.....Providence, R. I.
Clark, G. H.......New York City
Clark, J. A., Jr. East Orange, N. J.
Clark, L. V.....Philadelphia, Pa.
Clarke, St. John....Bogota, N. J.
Codwise, E. B....Kingston, N. Y.
Cogswell, W. B...Syracuse, N. Y.
Colby, S. K........New York City
Collier, B. C......New York City
Collingwood, F..Elizabeth, N. J.
Conrow, H........New York City
Cook, J. H.......Paterson, N. J.
Cooper, S. L......Yonkers, N. Y.
Cooper, T.........New York City
Copeland, W. R. Philadelphia, Pa.
Cornell, J. N. H...New York City
Corthell, A. B....New York City
Coverdale, W. H..New York City
Crane, C. A........New York City
Crane, F. E....Amsterdam, N. Y.
Craven, A.........New York City
Crehore, W. W....New York City
Creuzbaur, R. W..New York City
Croes, J. J. R.....New York City
Crowell, F........New York City
Cuddeback, A. W. Paterson, N. J.
Cudworth, F. G...New York City

Davies, J. V.......New York City
Davis, A. L.......New York City
Davis, Chas.......Allegheny, Pa.
Davis, R. B........Boston, Mass.
Davison, G. S......Pittsburg, Pa.
Dawley, E. P...Providence, R. I.
Dean, L..........Taunton, Mass.
Deans, C. H.......New York City
Deans, J. S......Phœnixville, Pa.
Devin, G..........New York City
De Witt, P. H.....New York City
Diebitsch, E......New York City
Dorrance, W. T...New York City
Dunham, H. F....New York City

Easby, M. W...Philadelphia, Pa.
Ehle, B........East Creek, N. Y.
Ellis, J. W....Woonsocket, R. I.
Erlandsen, O......New York City
Evans, J. M......Brooklyn, N. Y.
Evans, L. H.......New York City

Fernstrom, H.....New York City
Fisher, C..........Trenton, N. J.
Fisher, E. A.... Rochester, N. Y.

Fitch, C. L......Brooklyn, N. Y.
Francis, G. B.....New York City
Francis, H. N...Providence, R. I.
Frazee, J. H.......New York City
French, A. H....Brookline, Mass.
French, A. W...Worcester, Mass.
French, J. B......New York City
Frost, G. S.........New York City
Fuller, A. D.......Boston, Mass.
Fuller, F. L.......Boston, Mass.
Fuller, G. W......New York City
Fuller, W. B......New York City

Gartensteig, C.....New York City
Gifford, G. E .... New York City
Gillespie, R. H ...New York City
Goad, C. E ....Montreal, Canada
Goodnough, X. H..Boston, Mass.
Gould, E. S.......Yonkers, N. Y.
Gowen, C. S .... Ossining, N. Y.
Graham, C. H.....New York City
Grant, T. H.....Red Bank, N. J.
Green, B. R...Washington, D. C.
Greene, F. S......New York City
Greene, J. N.......Boston, Mass.
Gregory, C. E.....New York City
Gregory, J. H....Paterson, N. J.
Grimm, C. R......New York City

Hagar, E. M........Chicago, Ill.
Haight, S. S .....New York City
Hall, M. W.......New York City
Hammatt, W. C..Mexico, Mexico
Hammer, R. H.....New York City
Harlow, J. H...... Pittsburg, Pa.
Harper, A. C .....New York City
Harrington, J. L..New York City
Harris, C. M. ....New York City
Harrison, E. W.,
Jersey City, N. J.
Harwi, S. J.......Bayonne, N. J.
Harwood, G. A...Syracuse, N. Y.
Hatt, W. K....Washington, D. C.
Hatton, T. C...Wilmington, Del.
Hauck, W.........New York City
Haviland, A.......New York City
Hayes, E..........Cohoes, N. Y.
Hayes, S. W.......Geneva, N. Y.
Hazelton, C. W.,
Turner's Falls, Mass.
Hazen, A.........New York City
Hemming, D. W..New York City
Hendrick, C. W...New York City
Herbert, H. M.,
Bound Brook, N. J.
Hering, R........New York City
Herschel, C.......New York City
Hickok, H. A......Newark, N. J.
Hill, G...........New York City
Hoag, S. W., Jr....New York City
Hodgdon, F. W....Boston, Mass.
Hoffman, N. B. K..New York City
Holliday, A. R....Newcastle, Pa.
Hone, F. de P.....New York City
How, R. W.......New York City
Howe, E. W.......Boston, Mass.
Hudson, C. W...Phœnixville, Pa.
Humphrey, R. L.,
Philadelphia, Pa.
Hunt, Charles Warren,
New York City
Hutchings, W. E.,
Louisville, Ky.

Irving, W. E......New York City

Jacoby, H. S.......Ithaca, N. Y.
Jackson, W........Boston, Mass.
Jaques, W. H.....Boston, Mass.
Jarrett, E. S.......New York City
Johnson, A.......New York City
Johnson, A. L.....St. Louis, Mo.
Johnson, L. J..Cambridge, Mass.
Johnson, W. S.....Boston, Mass.
Just, G. A........New York City

Kaufman, G.....Brooklyn, N. Y.
Kelly, C. W. ..New Haven, Conn.
Kelly, O. M.......New York City
Kenney, E. F...Philadelphia, Pa.

Khuen, R., Jr.....Pittsburg, Pa.
Kimball, G. A.....Boston, Mass.
King, P. S........New York City
King, W., Jr......New York City
Knap, E. D.......New York City
Knap, J. M.......New York City
Knapp, L. H.......Buffalo, N. Y.
Knight, F. B......New York City
Knowles, M.......Pittsburg, Pa.

La Chicotte, H. A..New York City
Lamb, R..........New York City
Landreth, W. B....Albany, N. Y.
Latta, H. W....Philadelphia, Pa.
Lederle, G. A.......Chicago, Ill.
Lee, D. R.....Middletown, N. Y.
Lee, W. B........Hillburn, N. Y.
Leffingwell, F. D..Harrisburg, Pa.
Leisen, T. A ...Wilmington, Del.
Leonard, H. R..Philadelphia, Pa.
Lesley, R. W...Philadelphia, Pa.
Lewis, F. H......Craigsville, Va.
Lewis, M. H......New York City
Lewis, N. P........New York City
Lindenthal, G....New York City
Lofland, H. F.......Pencoyd, Pa.
Loomis, H........New York City
Low, G. E.........New York City
Lowinson, O.......New York City
Ludwig, J. A......New York City
Lund, G. A....Bridgeport, Conn.
Lundie, J..........New York City
Luster, W. H., Jr. Elizabeth, N. J.

Macdonald, A. A..New York City
Macdonald, C.....New York City
MacGregor, R. A..New York City
Machen, H. B......New York City
Maclay, W. W.....New York City
McComb, C. O..Watertown, N. Y.
McDonald, H. P., Jr.,
Jersey City, N. J.
McHarg, L........New York City
McKenzie, T. H.,
Southington, Conn.

McMinn, T. J.....New York City
McNicol, J. A.....New York City
McNulty, G. W...New York City
Malukoff, A. J....New York City
Manley, H.........Boston, Mass.
Marden, H. H., Jr..New York City
Marple, W. M......Scranton, Pa.
Martin, C. C......Brooklyn, N. Y.
Martin, W........New York City
Mason, F..........New York City
Mead, C. A.,
Upper Montclair, N. J.
Mead, E.......Washington, D. C.
Meem, J. C.......New York City
Merriman, M.....Bethlehem, Pa.
Merriman, T......New York City
Merryman, W. C..New York City
Metcalf, L.........Boston, Mass.
Miller, H. A.......Clinton, Mass.
Miller, H. C.......New York City
Miller, R. P ......New York City
Moisseiff, L. S.....New York City
Moore, C. H.......New York City
Moore, W. H..New Haven, Conn.
Morse, C. A......La Junta, Colo.
Moulton, M....Springfield, Mass.
Myers, C. H.......New York City
Myers, J. H.......New York City

Neumeyer, R. E...Bethlehem, Pa.
Nichols, C. H..New Haven, Conn.
Nichols, O. F.....Brooklyn, N. Y.
Noble, A..........New York City
North, E. P.......New York City

O'Brien, J. H......New York City
Ockerson, J. A....St. Louis, Mo.
Odell, F. S...Port Chester, N. Y.
Olney, L. F.......New York City
O'Rourke, J. F....New York City
Orr, A........Gloversville, N. Y.
Osborn, F. C...Cleveland, Ohio
Owen, J...........Newark, N. J.
Oxholm, T. S.,
West New Brighton, N. Y.

Parker, A. McC...New York City
Parker, C. J........Rutland, Vt.
Parsons, W. B....New York City
Pegram, G. H.....New York City
Pitts, T. D.......New York City
Plimpton, A. L....Boston, Mass.
Pollock, C. D....Brooklyn, N. Y.
Potter, H. W......New York City
Pratt, W. A.......New York City
Pratt, W. A....Philadelphia, Pa.
Price, P. W.......Pittsburg, Pa.
Prout, H. G.......New York City

Quimby, H. H..Philadelphia, Pa.

Rafter, G. W....Rochester, N. Y.
Ramsey, E. P.....New York City
Raymond, W. G......Troy, N. Y.
Reed, D. A........Duluth, Minn.
Reed, W. B.......New York City
Reid, H. A.......Brooklyn, N. Y.
Reynders, J. V. W.,
Harrisburg, Pa.
Rice, G. S........New York City
Richardson, C....New York City
Richardson, C. L. Montclair, N. J.
Ricketts, P. C........Troy, N. Y.
Ridgway, R.......New York City
Riedel, A. E.....Montclair, N. J.
Rogge, J. C. L....New York City
Rosenberg, F....Montclair, N. J.
Russell, R. L....Brooklyn, N. Y.
Ryan, M. H.......New York City

Scarborough, F. W.,
Richmond, Va.
Schmitz, F. C.....New York City
Schneider, C. C. Philadelphia, Pa.
Sherrerd, M. R....Newark, N. J.
Shryock, J. G..Philadelphia, Pa.
Simpson, G.......New York City
Simpson, G. F....New York City
Sinclair, F. O....Burlington, Vt.
Skinner, F. W.....New York City
Smith, A.........New York City
Smith, C. W......New York City
Smith, J. W.......New York City
Smith, W. F......New York City
Snow, J. P........Boston, Mass.
Sooysmith, C.....New York City
Spencer, W. T. New Haven, Conn.
Sperry, H. M.....New York City
Spooner, A. N.... New York City
Stearns, F. L......New York City
Stearns, F. P.......Boston, Mass.
Steffens, W. F....New York City
Stern, E. W.......New York City
Stevens, A ....New York City
Stewart, J. H.....New York City
Stewart, J. M.....New York City
Stoddard, G. C...New York City
Strachan, J......Brooklyn, N. Y.
Strawn, T. C......Newark, N. J.
Strobel, C. L........Chicago, Ill.
Swain, G. F.......Boston, Mass.
Swensson, E....Pittsburg, Mass.
Swinburne, G. W..New York City
Swindells, J. S..Mt. Kisco, N. Y.

Tainter, F. S......Far Hills, N. J.
Taylor, C. F...East Boston, Mass.
Taylor, L. A.......Boston, Mass.
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Temple, W. H. G. Providence, R. I.
Tenney, G. O. Spartanburg, S. C.
Thackray, G. E...Johnstown, Pa.
Thomas, G. E.....New York City
Thomes, E. H.....New York City
Thomson, G. H...New York City
Thomson, T. K...New York City
Thornley, J.......New York City
Tibbals, G. A....Brooklyn, N. Y.
Tibbals, S. G....Brooklyn, N. Y.
Tighe, J. L......Holyoke, Mass.
Tilden, C. J.......New York City
Tingley, R. H...Providence, R. I.
Travell, W. B.
West New Brighton, N. Y.
Tribus, L. L.....New York City
Triest, W. G. F...New York City

Trotter, A. W.....New York City
Trout, C. E.......New York City
Tucker, L. W.....Albany, N. Y.
Turner, D. L......New York City
Turner, E. K......Boston, Mass.
Turrill, S. M.....Syracuse, N. Y.
Tuttle, A. S.......New York City

Ulrich, D.........New York City
Upham, R. D.....New York City

Value, B. R........New York City
Van Horne, J. G..New York City
Vier, H...........New York City
Vogleson, J. A. Philadelphia, Pa.
Vredenburgh, W., Jr.
New York City
Vrooman, M..Gloversville, N. Y.

Wadsworth, J. E..New York City
Wagner, S. T...Philadelphia, Pa.
Ward, C. D.......New York City
Ward, C. R.......New York City
Ware, R. W.....Plainfield, N. J.
Washington, W. de H.,
New York City
Watkins, F. W....New York City
Webster, A. L.....New York City
Webster, G. S..Philadelphia, Pa.
Webster, W. R.Philadelphia, Pa.
Weiskopf, S. C....New York City
Weston, R. S......Boston, Mass.
Wheeler, H. R....New York City
Wheeler, R. N....New York City
Whiskeman, J. P..New York City
White, L.........New York City
White, T. S.....Beaver Falls, Pa.
White, W. U ..Philadelphia, Pa.
Whitson, A. M....New York City
Wiggin, E. W.New Haven, Conn.
Wiggin, T. H......Boston, Mass.
Wiggins, W. D.....Toledo, Ohio
Wilcock, F. .....New York City
Wilgus, W. J.....New York City
Wilkes, J. K.New Rochelle, N. Y.
Williams, G. S......Ithaca, N. Y.
Williams, R. B., Jr.,
New York City
Williamson, F. S..New York City
Wilson, C. W. S.,
New Rochelle, N. Y.
Wölfel, P. L...Philadelphia, Pa.
Wright, J. B.....New York City

Zook, M. A......Plainfield, N. J.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, March 4th, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership and ballots on the proposed amendment to the Constitution will be canvassed, and a paper by M. H. Gerry, Jr., Assoc. M. Am. Soc. C. E., entitled "A High-Voltage Power Transmission," will be presented for discussion. This paper was printed in *Proceedings* for January, 1903.

Wednesday, March 18th, 1903.—8.30 P. M.—At this meeting a paper by George W. Lilly, Assoc. M. Am. Soc. C. E., entitled "Sand-Blast Cleaning of Structural Steel," will be presented for discussion. This paper is printed in this number of *Proceedings*.

Wednesday, April 1st, 1903.—8.30 P. M. A regular business meeting will be held. Ballots for membership will be canvassed, and two papers will be presented for discussion, as follows: "The Filtration Works of the East Jersey Water Company, at Little Falls, New Jersey," by George W. Fuller, Assoc. M. Am. Soc. C. E.; and "Automatic Modules for Regulating the Speed of Filtration," by Charles Anthony, Jr., M. Am. Soc. C. E. These papers are printed in this number of *Proceedings*.

ADDITIONAL PAPER.

Attention is called to the paper entitled "Note on the Coefficient of Elasticity of Concrete and Mortar Beams During Flexure," by Myron S. Falk, Jun. Am. Soc. C. E., published in this number of *Proceedings*. This paper will not be presented for discussion at any meeting, but written communications on the subject are invited for publication, and its discussion may be called up by any member at any future meeting of the Society.

ANNUAL CONVENTION OF 1903.

The Thirty-fifth Annual Convention of the Society will be held at Asheville, N. C., during the week beginning June 8th, 1903.

ACCESSIONS TO THE LIBRARY.

From January 14th to February 10th, 1903.

DONATIONS.*

FOWLER'S ELECTRICAL ENGINEER'S YEAR-BOOK AND DIRECTORY OF LIGHT, POWER AND TRACTION STATIONS, 1903.

Leather, 6 x 4 ins., 479 pp., illus. Scientific Publishing Company, Manchester. 2 shillings 6 pence, net. Post free, 2 shillings 9 pence.

The preface states that in this book the work of revision has been extensive. Much new matter has been inserted, and among the additions are practical notes on the designing and testing of dynamos and motors. Some information is also given on rotary converters and switch-boards, electric welding, etc. A little pruning has been done to afford space for the fifty or sixty pages of new matter which has been added and the extensions in other directions which were desirable. In an appendix is given a directory of electric light and power stations throughout the United Kingdom, which furnishes the principal particulars of the pressures and methods of distribution as well as of boilers, engines, and electrical equipment, of between 400 and 500 stations. There is an index of nineteen pages.

AMERICAN ENGINEERING PRACTICE.

In the Construction of Rotary Portland Cement Plants, Designed and Erected by Lathbury and Spackman, Philadelphia, Pa. Cloth, 9 x 11 ins., 157 pp., illus. G. M. S. Armstrong, Philadelphia, 1902. $2.00. (Donated by *Cement and Engineering News.*)

In the Announcement the authors state that they offer to those interested, photographic and other illustrations of some of the plants that they have designed and constructed, and of the machinery they contain, all of which they have installed.

MANUAL FOR RESIDENT ENGINEERS.

Containing General Information on Construction. By F. A. Molitor and E. J. Beard. Cloth, 7 x 4½ ins., 4 + 118 pp., 13 tables. New York, John Wiley & Sons, 1903. $1.00.

During the construction of the Choctaw, Oklahoma and Gulf Railroad Company's line across the State of Arkansas in 1899, the first fifty pages of this book were written by the authors and published in blue-print form as "Instructions" to their resident engineers, with a view of obtaining uniformity of method in both work and results. When the company, in 1901, entered upon some 500 miles of extensions and branches separated from one another, making personal supervision difficult and slow, the authors revised the body of the book, and also the standard specifications of the company, which, together with the tables of level cuttings, were added to the original instructions and published in book form for the railroad company's use. After three years of private circulation, the authors have decided to present the "Manual" to the profession generally, and to the younger members particularly, with the hope that it may be as successful in standardizing and simplifying the work of resident engineers throughout the country as it has been in the instance of one railroad. There is an index of five pages.

CATECHISM OF THE LOCOMOTIVE.

By Matthias N. Forney. Second Edition, Revised and Enlarged. Cloth, 8 x 6 ins., 16 + 709 pp., illus. *The Railroad Gazette*, New York, 1897. $3.50.

Since the first edition of this work, in 1873, many changes and improvements have been made in the construction of locomotives, so that in preparing a second edition of the book the first one had to be thoroughly revised, and, to a great extent, rewritten. Also a great deal of entirely new matter had to be added to bring it up to the present state of the art of locomotive engineering. Most of the illustrations are entirely new, and have been selected from the latest practice in this country. The chapter headings are: Force and Motion; Resolution of Motion and Forces; The Principles of the Lever; The Forces of Air and Steam; On Work, Energy and the Mechanical Equivalent of Heat; The Steam Engine; The Expansive Action of Steam; The Slide-Valve; The Action of the Piston, Connecting Rod and Crank; General Description of a Locomotive Engine; Different Kinds of Locomotives; Locomotive Boilers; The Boiler Attachments; The

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* Unless otherwise specified, books in this list have been donated to the Library by the Publisher.

Throttle Valve and Steam Pipes; The Cylinders, Pistons, Guide-Bars, Cross-Heads and Connecting-Rods; The Valve-Gear; Action of the Pistons, Cranks and Driving-Wheels; Adhesions and Traction; Internal Disturbing Forces in the Locomotive; The Running Gear; Miscellaneous; Friction and Lubrication; Screw-Threads, Bolts and Nuts; Tenders; Water-Tanks and Turn-Tables; The Westinghouse Air-Brake; The Care and Use of the Air-Brake; The Eames Vacuum Driving-Wheel Brake; Proportions of Locomotives; Combustion; The Resistance of Trains; Performance and Cost of Operating Locomotives; The Care and Inspection of Locomotives while in the Engine House; Running Locomotives; Responsibilities and Qualifications of Locomotive Engineers; Accidents to Locomotives; Accidents and Injuries to Persons; Properties of Steam; Hyperbolic Logarithms. There is an index of twenty-nine pages.

PROCÉDÉS GÉNÉRAUX DE CONSTRUCTION TRAVAUX D'ART.

Par A. de Préaudeau, avec la collaboration de E. Pontzen. Tome Second: Construction des Ouvrages. Paper, 10 x 6 ins., 3 + 612 pp., illus., Paris, Ch. Béranger, 1903. 20 fr. (Donated by Ernest Pontzen.)

The Contents are: Fondations à l'air libre, à sec et sous l'eau; Procédés de consolidation du sous-sol, accidents; Fondations à l'aide de l'air comprimé; Entretien et réparation des ouvrages, démolitions; Travaux en élévation; Prix de revient (fondations, travaux en élévation).

ENGINEERING FOR LAND DRAINAGE.

A Manual for Laying Out and Constructing Drains for the Improvement of Agricultural Lands. By Charles G. Elliott, M. Am. Soc. C. E. Cloth, 7½ x 5 ins., 8 + 232 pp., illus. New York, John Wiley & Sons, 1903. $1.50.

The preface states that this brief treatise on drainage engineering is intended for the use of those who are charged with the responsibility of making plans for and executing drainage improvements. It puts the experience and practice of years into a form which will be available to others who wish to acquire quickly the principles and practice of land drainage. It has been the purpose of the author to emphasize and make clear those points which the student, the busy agriculturist, and the practical engineer should know. The chapter headings are: Introduction; Soils; Land Drainage Practice; Levelling and Topography; Laying out Drains in the Field; Fixing the Grade of Drains; Maps and Records; Grading the Ditches for Tile; Flow of Water through Pipes; Size of Lateral Drains; Open Drains; Drainage of Barnyards, Cattle-Lanes, etc.; Road Drainage; Drainage Districts; Estimates of Cost; Benefits and Profits of Land Drainage. There is an index of ten pages.

STEAM POWER PLANTS, THEIR DESIGN AND CONSTRUCTION.

By Henry C. Meyer, Jr. Cloth, 9 x 6 ins., 159 pp., illus. New York, McGraw Publishing Co., 1903. $2.00.

The publishers' note states that the matter in this book was written to give information to owners or managers of manufacturing plants or buildings requiring power installations, since they are from time to time called upon to specify or purchase the machinery needed for the proper equipment of their buildings with a view to efficiency and economy in operation. It is believed that the book will also prove valuable to the engineer, architect or student who desires general information on the subject treated. To the expert it claims only to present in accessible and convenient form data useful in the practice of his profession. The Contents are: Design of Steam Power Plants; Proportioning Steam Boilers; Design of Tubular Boilers and Boiler Specifications; Selection of Engines; Specifications for Steam Engines; Steam and Water Piping; Condensers; Feed Water Heaters and Economizers; Mechanical Draft; Chimneys; Coal Handling, Water Supply and Purification.

THE MANUFACTURE AND PROPERTIES OF IRON AND STEEL.

By Harry Huse Campbell, M. Am. Inst. Min. E., M. Am. Soc. C. E., M. Iron and Steel Inst. Second Edition. Cloth, 9 x 6 ins., 29 + 862 pp., illus. New York, *The Engineering and Mining Journal*, 1903. $5.00. (Donated by the Author.)

In this present edition the author has tried to give in Part I a kind of introduction for those who are not metallurgists. It does not pretend to give all the qualifying conditions, but simply the main principles. Part II embraces the ground covered by the first edition of Structural Steel, but many chapters have been entirely rewritten, and a great deal of new matter added. Much of the text relating to the chemical history of the open-hearth furnace has been condensed from certain papers which the author contributed to the *Transactions* of the American Institute of Mining Engineers, while portions of chapters appeared in the *Transactions* of the American Society of Civil Engineers. The experiments and investigations have been conducted at the works of

The Pennsylvania Steel Company, of Steelton, Pa., and all the details of manufacture and treatment have been under the author's direct observation. In Part III the author has entered into a more comprehensive comparison of the industrial situation, and has compared the salient points of foreign and American practice. The Contents are: The Main Principles of Iron Metallurgy; The Errancy of Scientific Records; The Blast Furnace; Wrought-Iron; Steel; High-Carbon Steel; The Acid-Bessemer Process; The Basic-Bessemer Process; The Open-Hearth Furnace; Fuel; The Acid Open-Hearth Process; The Basic Open-Hearth Process; Special Methods of Manufacture and Some Items Affecting the Costs; Segregation and Homogeneity; Influence of Hot Working on Steel; Heat Treatment; The History and Shape of the Test-Piece; The Influence of Certain Elements on the Physical Properties of Steel; Classification of Structural Steel; Welding; Steel Castings; The Iron Industry of the Leading Nations. There is an index of twenty-two pages.

Gifts have also been received from the following:

Am. Inst. of Min. Engrs. 16 pam.
Ariz. Agri. Exper. Station. 1 pam.
Arnold, Bion J. 2 vol.
Australasian Inst. of Min. Engrs. 2 pam.
Boston, Mass.—Pub. Lib. 1 pam.
Boston, Mass.—Transit Comm. 1 bound vol.
Buffalo, N. Y.—Deputy Water Commr. 1 vol.
Cambridge, Mass.—Water Board. 1 pam.
Canadian Inst. 1 vol.
Conn.—R. R. Commrs. 1 bound vol.
Damascus Steel Co. 1 pam.
Deutsch-Amerikanischer Techniker-Verband. 1 pam.
Ellis, G. E. 1 bound vol.
Fisher, E. A. 1 vol.
Ford, Frederick L. 1 pam.
Great Britain—Patent Office. 6 pam.
Iowa Eng. Soc. 6 pam.
Iron and Steel Inst. 1 bound vol
Macmillan Co. 1 bound vol.
McMinn, T. J. 1 pam.
Mass.—Harbor and Land Commrs. 1 bound vol.
Miles, John W. 1 pam.
New England Cotton Mfrs. Assoc. 1 bound vol.
New South Wales—Ry. Commrs. 1 bound vol.
New York World. 1 vol.
Nichols, Charles H. 2 bound vol.
Pharr, H. N. 3 pam.
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Sweet, Elnathan. 1 pam.
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Switzerland—Eiden. hydrometrisches Bureau. 1 pam.
Thurston, R. H. 1 pam.
Tutein-Nolthenius, R. P. J. 1 pam.
U. S. Bureau of Foreign Commerce. 2 pam.
U. S. Chief of Engrs. 2 bound vol.
U. S. Coast and Geodetic Surv. 1 bound vol.
U. S. Geological Surv. 2 bound vol., 22 pam.
U. S. Weather Bureau. 1 bound vol.
Univ. of Ill. 1 pam.
Univ. of Ill. Agri. Exper. Station. 1 pam.
Univ. of Texas Mineral Surv. 1 pam.
Weir Frog Co. 1 bound vol.
Unknown Donors. 2 pam.

BY PURCHASE.

Rivières Canalisées. Par F. B. de Mas. Paris, Ch. Beranger, 1903.

The Analysis of Steel-Works Materials. By Harry Brearley and Fred Ibbotson. Longmans, Green and Co., London, New York and Bombay, 1902.

United States Official Postal Guide, January, 1903. Revised and Published Monthly by Authority of the Post Office Department. Contains an Alphabetical List of All the Post Offices in the United States with County and State, a List by States, a List by States and Counties, Showing the Money-Order Offices, Domestic and International; also, Rates of Postage; Synopsis of Postal Laws, Orders, Rulings of the Department; Information Relating to Postal Matters; and General Regulations Respecting Foreign Mails. Philadelphia, George F. Lasher.

SUMMARY OF ACCESSIONS.

From January 14th to February 10th, 1903.

Donations (including 10 duplicates)	111
By Purchase	3
Total	114

MEMBERSHIP.

ADDITIONS.

MEMBERS.

		Date of Membership.
Allan, Percy Public Works Dept., Sydney, N. S. W., Australia	Assoc. M. M.	April 1, 1896 Oct. 1, 1902
Barnard, Edward Chester Topographer, U. S. Geological Survey, Washington, D. C.		Dec. 3, 1902
Dyer, Arthur James Engr. in chg., Great Falls Power Co., Nashville, Tenn.	Assoc. M. M.	Mar. 6, 1901 Feb. 4, 1903
Fitch, Graham Denby Capt., Corps of Engrs., U. S. A., U. S. Engr. Office, Little Rock, Ark.		Feb. 4, 1903
Sherman, Charles Winslow Div. Engr., Sudbury Dept., Met. Water-Works, 1 Ashburton Pl., Boston, Mass.	Jun. Assoc. M. M.	Oct. 8, 1891 May 2, 1900 Feb. 4, 1903
Thompson, Henry Clark Div. Engr., N. Y. C. & H. R. R. R., 42 Lorillard Pl., Fordham, New York City		Feb. 4, 1903
Wisner, George Monroe Asst. Chf. Engr., San. Dist. of Chicago, 1010 Security Bldg., Chicago, Ill		Feb. 4, 1903

ASSOCIATE MEMBERS.

Ashbaugh, Lewis Eugene Asst. Prof. of Civ. Eng., Iowa State Coll., Ames, Iowa		Jan. 7, 1903
Aubyansen, Frederick Chf. Draftsman, Atlantic Ave. Impvt., L. I. R. R., 44 Court St., Brooklyn, N. Y.	Jun. Assoc. M.	Oct. 5, 1897 Dec. 3, 1902
Bacon, George Morgan 624 Dooly Blk., Salt Lake City, Utah		Dec. 3, 1902
Bantel, Edward Christian Henry Instr. in Civ. Eng., Univ. of Texas, 2600 Whitis Ave., Austin, Tex.		Feb. 4, 1903
Bradshaw, Sam Wigfall Asst. Engr., Estimating Dept., Pennsylvania Steel Co., Steelton, Pa	Jun. Assoc. M.	Oct. 2, 1900 Feb. 4, 1903
Dana, Richard Turner Railroad Location and Gen. Engr., Room 206, Bennett Bldg., New York City	Jun. Assoc. M.	Sept. 11, 1900 Feb. 4, 1903
Day, Edward Bliss Office Engr., Burlington's Missouri Lines, Room 610, Globe Democrat Bldg., St. Louis, Mo.		Feb. 4, 1903
Ferguson, William Hastings (Best & Ferguson, Cons. Engrs.), 16 Ferguson Bldg., Denver, Colo.		Jan. 7, 1903

		Date of Membership.
HALL, CHARLES ROMNEY		
U. S. Eng. Dept., Fort McKinley, Portland Harbor, Me..		Jan. 7, 1903
JAUDON, HENRY SCUDDER		
Care, Birmingham Water-Works Co., Birmingham, Ala...		Feb. 4, 1903
McKAY, GEORGE ALBERT		
Civ. Engr., U. S. N., Narragansett Bay Coal Depot, Newport, R. I.		Feb. 4, 1903
ROCKWELL, JAMES VINCENT		
Asst. Engr., C. & N. W. Ry., Eagle Grove, Iowa	Jun. Assoc. M.	April 3, 1900 Feb. 4, 1903
SHEPARDSON, JOHN EATON		
Shabbona Grove, De Kalb Co., Ill.		Jan. 7, 1903
TOMPKINS, EDWARD DE VOE		
Chf. Draftsman, Bureau of Yards and Docks, U. S. Navy Yard, League Island, Philadelphia, Pa.	Jun. Assoc. M.	Feb. 2, 1897 Dec. 3, 1902
WHEELER, RALPH NORMAN		
With Rapid Transit R. R. Comm., 13 Astor Pl., New York City		Jan. 7, 1903
WHITE, LAZARUS		
18 West 119th St., New York City	Jun. Assoc. M.	May 1, 1900 Feb. 4, 1903

ASSOCIATES.

KELLER, OTTO BALTHAZAR	
127 Fulton St., New York City	Feb. 3, 1903
QUIRK, EUGENE McGRATH	
Mgr., Montreal Quarry Co., 266 Boulevard, Ville St. Louis, Montreal, Que., Canada	Feb. 3, 1903

JUNIORS.

BASSETT, ROBERT JAY	
25 North 4th St., Steelton, Pa.	Feb. 3, 1903
DOUGHERTY, RICHARD ERWIN	
244 West 20th St., New York City	Jan. 6, 1903
FUJINO, SHUKICHI	
Bridge Engr., Nippon Tetsudo Kwaisha, Tokyo, Japan...	Feb. 3, 1903
GEORGE, HUGH MELVIN	
Care, Water Co., Meridian, Miss.	Feb. 3, 1903
KOLB, HENRY JACOB	
Care, Dr. Dillworth, Bedford Park, New York City	Feb. 3, 1903
PEARSE, LANGDON	
317 Walnut Ave., Roxbury, Mass.	Jan. 6, 1903
TOMBO, CARL	
273 West 138th St., New York City	Feb. 3, 1903
WILDES, WALDO GILMAN	
208 Church St., Clinton, Mass.	Feb. 3, 1903

RESIGNATIONS.

MEMBERS.

	Date of Resignation.
SEE, HORACE	Dec. 31, 1902
WALTON, CHARLES WALLACE	Dec. 31, 1902

DEATHS.

BARRIGER, JOHN WALKER, Jr.	Elected Junior, May 31st, 1898; Associate Member April 2d, 1902; died December 19th, 1902.
FUERTES, ESTEVAN ANTONIO	Elected Member February 17th, 1869; died January 16th, 1903.
RICH, WATSON WELLMAN	Elected Member September 5th, 1883; died January 12th, 1903.
SWEET, ELNATHAN	Elected Member November 6th, 1878; died January 27th, 1903.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(January 14th to February 10th, 1903.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Eng. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des Ecôle Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

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PAPERS AND DISCUSSIONS.

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SAND-BLAST CLEANING OF STRUCTURAL STEEL.

By George W. Lilly, Assoc. M. Am. Soc. C. E.

To be Presented March 18th, 1903.

It is intended to set forth, in this paper, some of the results which have been attained in the use of the sand-blast in cleaning steel plates and structural steel. Some data as to the cost and other elements which enter into its application will be presented, in the hope that possibly something may be added to the facility of making approximately accurate estimates of the cost of any sand-blast cleaning which may be in contemplation hereafter. Some of the work heretofore done has been referred to in a paper, published in *Engineering News* of April 24th, 1902; and in it the cost of cleaning 12 600 sq. ft. of the Front Street Viaduct over the Little Miami Railroad, in Columbus, Ohio, was stated. In presenting the experience gained in the continuance of the work during the season of 1902, giving results in cleaning a total area of 135 500 sq. ft. on viaducts in that city, which have been repainted since the early part of November, 1901, it is hoped to add a record of at least some value.

If it leads to a thorough discussion, and if members of the Society add to the record, the most important part of the purpose in presenting this paper will have been realized.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

During the past few years some attention has been given to attempts to secure thorough cleaning of structural steel before the application of the preservative coating; but, unfortunately, we are still far from the realization of the kind of work which should be required. Much has been written relative to the kind of paint which will best preserve the steel and iron used so extensively in a great variety of structures. In the discussion, which has been going on for many years, many have argued very strenuously against, and many just as earnestly in favor of, perhaps every kind of paint now used largely as preservatives of ferric structures from the ravages of rust and corrosion. But, in the discussion, they have often lost sight of the very important matter of cleaning the steel properly. On account of the great deterioration of such structures, in the past, whether by reason of exposure to the weather on land or at sea, or to the action of acids, or the gases and moisture of coal combustion, in combination with the oxygen of the atmosphere, this is a question of vital interest to all engineers and others concerned in their erection or maintenance. Nevertheless, comparatively little has been done thus far toward securing such cleaning as will insure a much longer life for, as well as economy in the maintenance of, such structures. The dawn of a better day seems to have appeared, in the application of better methods, in some instances, on new work, and, in more cases, on the old; and it is to be hoped that the full light of that day may soon be seen, in the results on new work in the shop—as a provision for the future—and on old structures—to undo, as far as possible, the neglect of the past.

It has often been observed that mill marks made with paint of a very inferior quality have afforded good protection to steel, while other portions, covered with a much better paint, have been much affected by rust, the latter even extending under paint which, for the most part, has still retained its continuity and elastic qualities. The explanation is found in the facts that the mill marks were made when the metal was clean, and that the paint applied subsequently was spread upon the mill scale, rust and grease which had accumulated upon it before the shop work was finished. However excellent may be its qualities, it is absurd to expect any paint to preserve steel to which it is applied, unless the mill scale, rust, dirt and grease have been first removed. This observation applies with equal, or, it may be said, with even greater, force, to the repainting of old structures which have been neglected, and upon which rust and corrosion have proceeded so far that it is impossible to secure good preservation by ordinary methods of cleaning. Having this knowledge in mind, it is proper to determine, from the conditions met in any case, what is necessary to be done in order to insure that the preservative coating shall be applied only after the surface of the metal is clean and in proper condition to receive it. To accomplish this, there is no doubt that much of the new as well as old steel will be required to be cleaned by means of the sand-blast, as the only practicable and effective method. Much of the steel, after leaving the mills, is stored out-of-doors and exposed to the weather for a considerable length of time before the shop work is done. Thus its rusting often progresses to such an extent that the ordinary process of cleaning with wire brushes, even if that be attempted, is not sufficient to permit the paint to come into immediate contact with and become firmly adherent to the metal. The quality of the paint used, on new structures as well as old, is an important matter; but that cannot be discussed in this paper.

The effectiveness of the sand-blast process depends upon the ability of sand, used as a projectile, to break up, wear away and remove the substances against which it is directed, when actuated by a current of compressed air. All the machines, often called mixers, for the application of this process, are intended to secure the introduction of the proper proportion of sand into a current of compressed air passing through a pipe. This current of compressed air, bearing with it the sand thus introduced, is then directed into and through rubber hose, preferably 2¼ or 2½ ins. in diameter, and a steel or iron nozzle of suitable size, and against the surface to be cleaned. Sometimes the air-blast alone may be used to remove dust and soot. Such an appliance was first invented and patented by General Benjamin C. Tilghman, the patent being issued on October 18th, 1870. This appliance, as improved by Mathewson, is still on the market. In this apparatus, a slotted slide, operated by a lever, regulates the quantity of sand introduced into the current of air. This is shown by the sectional drawing, Fig. 1.

In the Paxson-Warren machine, Fig. 2, the feed of the sand is regulated by a revolving piece, or valve, which covers the opening in the bottom of the hopper to the extent desired to let the proper quantity of sand fall through it and into the air pipe.

In the machine patented by J. M. Newhouse, of Columbus, Ohio, shown in Fig. 3, the sand passes from the hopper at the bottom through an annular opening around the end of a nozzle-shaped steel piece, which decreases in its outer circumference toward the end; and, by raising or lowering it, this annular opening may be increased or diminished in size. The distinguishing feature of this appliance is

MATHEWSON'S SAND-BLAST.
(TRADE NAME, TILGHMAN.)

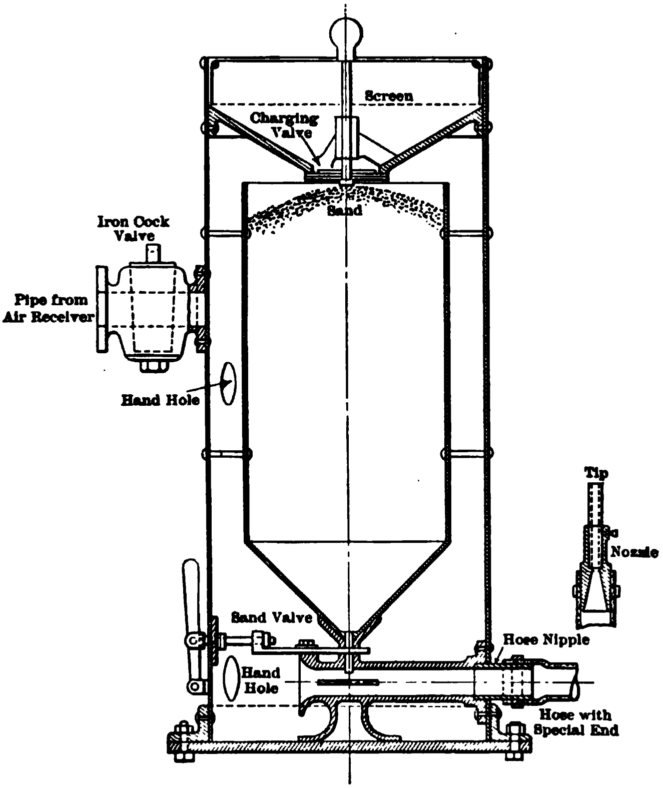


FIG. 1.

the use of this nozzle as a siphon, with its perforations as shown. The small holes permit part of the air which flows through the small pipe and the siphon to escape outwardly through the surrounding sand, thus stirring it up and preventing it from clogging at the opening. A similar siphon, without the perforations, is placed in the air pipe.

Possibly there are other machines, but the writer is not familiar with them. Any of the sand mixers may be made with two chambers, with valves arranged so as to lock the sand through the upper one into the lower one while the sand-blast is in operation.

The greatest merit of the sand-blast is that it removes from the surface of the metal every trace of dirt, scale, rust and grease, and the bright metallic surface is everywhere exposed and perfectly clean. This is an ideal condition to secure the strong adhesion of the paint, so that, as far as it is possible, it will protect the metal. The thoroughness of the cleaning effected by the sand-blast is noted especially upon metal surfaces which have been pitted by rust and corrosion to a considerable degree. The pits are thus cleaned as thor-

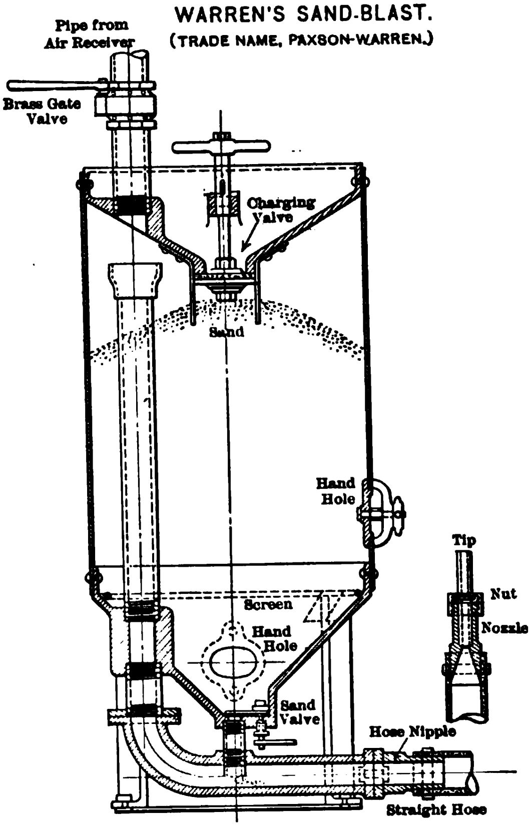
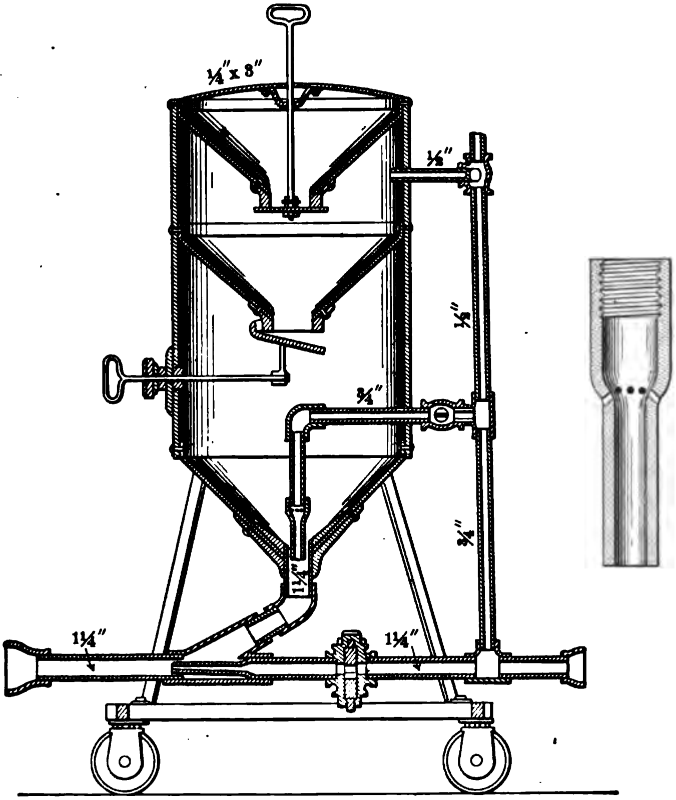


FIG. 2.

oughly as other places. It also reaches and cleans effectually every portion, in re-entrant angles and on the edges of the different sections of a beam, girder or post, on and around rivet heads, and in many other places either entirely inaccessible to the wire-brush or steel scraper, or on which they are used with great difficulty and little effect.



THE NEWHOUSE SAND-BLAST.
Fig. 3.

Such places cannot be cleaned thoroughly by hand, even with the most diligent effort. Even plane surfaces of considerable area, on old structures requiring repainting, especially where covered largely with scales and rust, cannot be thus cleaned so as to remove all the dirt, rust, scale and disintegrating paint. There will still remain sufficient rust and scale to separate slightly the paint from the metal, so that there is not the intimate contact and firm adhesion necessary to prevent the rusting process. The continuity of the coat of paint will soon be broken at places, and, moisture and gases in the atmosphere coming in contact with the metal, rust will be formed even under places where the paint remains intact.

Paint applied to such surfaces can often be stripped off like the peel of an orange, and still remains tough and elastic. Good paint, it may be, but it has never taken a good hold on the steel. On the other hand, the writer has seen a piece of old steel, which was cleaned and painted with red lead in 1899, on which the paint will not peel off at all, but may be cut away, still leaving the under portion tightly adhering to the steel.

The sand-blast has been found serviceable and economical for other purposes than the cleaning of steel plates and structural steel. It is used in cleaning iron and brass castings, either by the direct application of the blast, or by introducing the sand-blast through the hollow trunnion of the tumbling barrel in which the castings are placed. The inner, as well as the outer, surfaces of castings are thus cleaned, and the sharp lines of the edges preserved, while the cleaning effected by the tumbling barrel without the sand-blast tends to round off the corners. Its use to clean street-railway rails and fish-plates, for cast and electric welding, is familiar to all. It is also quite effective in cleaning cut-stone work. One of the ice-manufacturing companies of Columbus, Ohio, has recently purchased a sand-blast machine for use in removing from its condenser pipes the lime scale formed from the hard water used.

The Columbus Railway Company has made use of it in cleaning about 18 ins. in length of a large number of its iron trolley poles, just above and below the surface of the ground. At this point the poles had rusted to such an extent as to weaken them materially, and it would soon have been necessary to replace many of them. After cleaning in this way, a coat of paint was immediately applied, and, soon afterward, each pole was encased in a cylinder of cement mortar tamped into removable forms.

The sand-blast has also been used at the shops of the Pan Handle Railway, and in other railroad shops, in cleaning the tenders of locomotives before repainting. A great saving of expense is thus realized, and superior work is obtained. It would be attempting too much to take up the methods and relative costs in these various lines of sand-blast work.

It seems that, beyond a few scattered experiments, only during the past six or seven years may be found any published record of the application of this process to the cleaning of structural steel. And, even in these recent years, no very great amount of such cleaning has been done. Most of the trials heretofore made have been upon a somewhat experimental basis, and yet something may be learned from them. It is still rather problematical as to how cheaply the mill scale, rust and grease could be cleaned from new steel plates and structural steel, if an efficient permanent plant were provided for the purpose. Some new plates for the bilge keels of the *Massachusetts* were cleaned at the United States Navy Yard, Brooklyn, in April, 1897. With one nozzle, 3 155 sq. ft. of surface were cleaned in 11 hours. This is at the rate of 286.8 sq. ft. per hour. The cost of the work was 0.56 cent per square foot. Upon this basis the writer estimated that the sand-blast cleaning of new steel plates, I-beams and other sections, would cost from 50 cents per ton, for very heavy sections, to $1.75 per ton, for light sections. This would not be a very large additional expenditure upon steel structures, considering the longer life which it would, no doubt, insure for the steel thus treated. The rapid deterioration and wasting away which has been observed on bridges and other structures may well cause builders of steel-framed buildings to consider the advisability of cleaning the steel in this way, before painting it and hiding it from inspection in the walls. The safety as well as the durability of such buildings may depend upon better provision against the rusting out of these steel frames. Who knows?

The steel for the anchorages of the cables of the New East River Bridge were cleaned by the sand-blast, under the direction of L. L. Buck, M. Am. Soc. C. E., Chief Engineer. This was done for the special reason that it would be "buried in the masonry, and would be totally inaccessible for all time." This process was also used on some of the steel in the Boston subways, Howard A. Carson, M. Am. Soc. C. E., Chief Engineer. The writer has no figures as to the cost in these cases.

Much of the expense of repainting in the future would be saved if greater care were taken in securing thorough cleaning at the shops before applying the first coat of paint to new work. If this is to be accomplished, it will in many cases be found necessary to use the sand-blast; but this will not be done until the purchaser is willing to pay for it; and he must be convinced of its necessity and ultimate economy before he will be willing to do so. When there is a demand for it, the shops will be equipped with the necessary machinery, and will be able to do it more cheaply. At present, one shop has to bid against the other, and, none of them being required to make bids with such cleaning as a part of the specifications, the bids are such that the shops probably cannot afford to clean the steel properly, in some instances at least. They are averse to this process because of the expense of fitting up for it, the delay in getting the work out, and the cost of handling. Therefore the purchaser must be the prime mover in securing such work.

In the cleaning of old structures for repainting, this process has been more extensively applied, and, therefore, there are better data relative to such work than as to the cost of cleaning new steel at the shops. The necessity of its use to preserve old structures requiring repainting is more apparent than the more remote future saving of the expense of its application for repainting, by a much smaller outlay to secure thorough cleaning before erection.

During the latter part of March and the first two days of April, 1897, the bottom of the United States Steamship *Atlanta* was cleaned at the United States Navy Yard, Brooklyn, by means of the sand-blast, the plant used being furnished by Ward and Nash, of 26 Whitehall Street, New York City, who had the contract for the work. Its cost was 4.24 cents per square foot; but the work was done on a more or less experimental basis, and, with the added experience of the past six years, and a more perfect plant, it could probably be done for much less.

The work done on the One Hundred and Fifty-fifth Street Viaduct, in New York City, under the direction of E. P. North, M. Am. Soc. C. E., Consulting Engineer, during the year 1897, is familiar to all.* The cost of this work was reported as averaging about 13 cents per square foot, ranging from 20 cents, at the first, down to a little less than 10 cents, in the latter part of the work of cleaning 50 000 sq. ft. of surface. The pressure of compressed air then used was only about 20 lbs. at the sand-blast apparatus, which is without doubt too low a pressure for the efficient removal of scale such as had accumulated there. It would seem, from recent experience, that a pressure of 35 lbs. would have been much more effective. This is true, because the viaduct was covered to a considerable extent with heavy rust scale and four layers of old paint, and a pressure of 35 lbs. would have made the sand projectiles much more efficient in breaking up and throwing off such scale. M. E. Evans, Assoc. M. Am. Soc. C. E., who was in immediate charge, estimated that the 600 000 sq. ft. of the painting surface of the viaduct could be cleaned for about 7.5 cents per square foot. It is quite probable that this could be done now at half that estimate, at least on all portions of the viaduct except the members having a very small extent of surface, where much sand and air are wasted in missing the steel along the edges.

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* *Engineering News*, September 23d, 1897, p. 198; *The Engineering Record*, September 25th, 1897, p. 356; and other engineering periodicals.

The next work of this kind reported upon was the cleaning of the iron lock-gates and a portion of the aqueduct of the Muscle Shoals Canal, during the years 1898 and 1899, under the engineers of the United States War Department. The first report of this, made before its completion, is found in the House Documents for 1898–9.* This covers the work done to June 30th, 1898; and, on page 1926, Major Kingman states that the cost for cleaning was about 2.3 cents per square foot. In the report† of Sydney B. Williamson, M. Am. Soc. C. E., made after the completion of the work in 1899, the cost of cleaning 49 664 sq. ft., and painting it with red lead, is stated to be $0.0588 per square foot. Allowing a reasonable amount for the painting, it is probable that 3 cents per square foot would be very near the cost of the cleaning alone. In this case the plant was erected on a barge, roofed over, and was very well arranged to accomplish the work. The cost of the plant was included in this statement, and the same plant could be used for continuing such work. This cost was about one-third of the whole cost of cleaning and painting.

During the year 1899 the Pittsburg, Cincinnati, Chicago and St. Louis Railway Company used the sand-blast for cleaning the columns and girders supporting its buildings over the railroad tracks, along the east side of the High Street Viaduct, in Columbus, Ohio. The girders support brick arches, and there are no buckle plates. They are subjected to the blast, gases and steam from the large number of locomotives passing to and from the Union Depot, and freight and switch engines passing under them at frequent intervals. This company also cleaned part or all of a bridge at Akron, Ohio. No accurate account was kept of the cost and the area cleaned; but, from the best available information, it is estimated to have been about 3 cents per square foot. J. M. Newhouse, the inventor and patentee of the Newhouse sand-blast, is foreman for this company, and his apparatus was used in doing the work.

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* War Department Reports, Engineers, Part 3, p. 1925 *et seq.*

† Engineer's Report, Part 3, p. 2289, House Doc. for 1899 to 1900.

The City of Columbus, Ohio, has six viaducts in the vicinity of the Union Station, by which the streets pass over the railroad tracks. All the railroads passing through the city, except one, enter and leave the Union Station under the Fourth Street Viaduct near the east end, and the High Street Viaduct near the west end; and some of them pass under each of the other viaducts, one to the west and three to the southwest from the High Street Viaduct. Besides the freight and passenger trains passing under them, much switching is done under each by the yard engines. Hence, all these viaducts have been attacked seriously by rust and corrosion; and, on the portions most exposed to the blast, steam and gases from the locomotives, nearly all the paint has been destroyed and the metal consumed to a considerable extent. The Fourth Street Viaduct has been injured most, and two years ago it was cleaned by hand and repainted. This viaduct was erected in 1891, and was repainted in June, 1894, in September, 1896, and again, at the time above mentioned, in the fall of 1900. When the last repainting was progressing it was found necessary to replace with new ones seventeen of the 7-in. I-beams supporting the plank floors of the sidewalks over the tracks most used by freight trains and yard engines. Fig. 1, Plate XVI, is from a photograph of three of these I-beams, taken after their removal, after nine years' service. At the time this was done, the lower flange-angles of many of the stringers supporting the buckle-plates under the roadway had been rusted away until very thin; and in places the horizontal legs of the angles had been partly eaten away, so as to narrow them to about half their original width. These, however, were still considered of sufficient section to last for a time, and were not replaced then. The viaduct was painted under a contract, and considerable care was taken in trying to clean it as thoroughly as possible with steel scrapers, brushes, chisels and hammers. The hammers were often vigorously used to jar the scales loose by blows against the steel, and then scrapers, chisels and wire brushes used to complete the work.

At that time the sand-blast was suggested by the Engineering Department, but was not used. With as thorough work as could be done, many scales, so tightly cemented to the steel that they could not be detached, were loosened, upon the application of the first coat of paint, by the softening effect of the oil acting upon the cementing rust. The paint then applied began to scale in places within six months thereafter, partly due to the inferior quality of the first coat of paint and partly to the rust, soot and scale left upon the steel when repainted. The flange-angles of the floor stringers continued to waste away, and, in the summer of 1902, it was found necessary to replace, by new ones, the two angles of the lower flange on each of ninety floor stringers. The need of this is apparent from Plate XV, which is a photograph of some of the angles taken after their removal.

The new angles were surrounded with a covering of Portland cement mortar, 1 to 2 mixture, about ¾ to 1 in. thick. This was rammed under the lower surface of each beam, between it and a plank form, which was left to hold it against the steel until it had set for 48 hours. A wire netting, four meshes to the inch, secured by sheet-iron fasteners placed on the rivets as they were driven, was placed so as to surround the lower flange-angles before the cement mortar was applied. The cement covers the angles and netting completely, and is expected to protect them from rust. After seven months the cement is still intact, and shows no sign of cracking.

In view of the rapid deterioration of the viaducts of the city, and the prospect of having to replace them in a few years unless something were done to arrest it, the city authorities were induced to adopt the sand-blast as a means of cleaning them before repainting. Julian Griggs, M. Am. Soc. C. E., Chief Engineer of the Department of Public Improvements, had been very earnest in the advocacy of this course, believing it to be the only one that would be effective. Accordingly, in November, 1901, the work was commenced on the Front Street Viaduct, over the Little Miami Railroad, and 12 600 sq. ft. were cleaned and repainted, under the supervision of the writer as engineer in charge. When the weather became suitable for it, in April, 1902, the work was resumed and continued on this and the other viaducts named until the middle of November. The cleaning done amounted, in all, to 135 500 sq. ft. of surface. The cost and other data relative thereto are shown in Table No. 1. Four viaducts and the south span of the High Street Viaduct were completed. It is likely that the other three spans of the High Street Viaduct, and the Fourth Street Viaduct, will be cleaned and repainted during the coming season of 1903.

It was impracticable to secure good contract work at a reasonable price, and all the sand-blast cleaning, as well as the painting, was done by men hired by the day. Two Newhouse sand-blast machines, mounted on light trucks, so that they could be moved about and placed where convenient for the work, were used in cleaning the viaducts named in Table No. 1. A wire-bound, 1½-in., rubber air-hose, 50 ft. in length, connected each machine with the 2-in. air pipe. Old rubber hose, which was much cheaper than new, was used for the sand hose, part of it being 2¼ and part 2½ ins. in diameter. The nozzles used were ½-in., extra heavy, gas pipe, of various lengths, from 12 to 24 ins. A length of at least 12 ins. seems to direct the blast with more effect than a shorter one. This was used instead of tool steel or other hard pipe because it was believed that it would last nearly as long and cost much less. The average length of time one nozzle lasted was about 5 hours, as shown by the length of pipe used and the total hours run. The nozzle was connected to the sand hose by a heavy, special cast reducer, about ¾ in. thick. This is shown in Fig. 2, Plate XVI, which also shows a blower used at the High Street Viaduct. This reducer was made thick, to sustain the wear caused by the deflection of the sand into the small nozzle pipe. The most severe wear of the nozzles is at a point 3 ins. from the connection with the reducer. The four worn nozzles, in Fig. 3, Plate XVI, show the characteristic form of the failure of the nozzles when worn out. The one at the right was selected as a rare exception, it being worn out at the outflow end. The three-part nozzle at the left wore out toward the center, and also just outside of the bushing, in which the three ¼-in. pipes were set with babbitt metal. This nozzle was made only for the purpose of a test, which is recorded in Table No. 2. After the test, it was used until worn out, and lasted, in all, 1 hour and 19 minutes.

It will be noted that the sand, in passing from the large sand hose to the small nozzle, is deflected so as to produce a cross-fire, striking with greatest force against the sides of the small pipe near the reducer end. A like wear upon the rubber sand hose occurs near its connection with the pipe from the machine, which is a 1¼-in. pipe, and the

PLATE XV.
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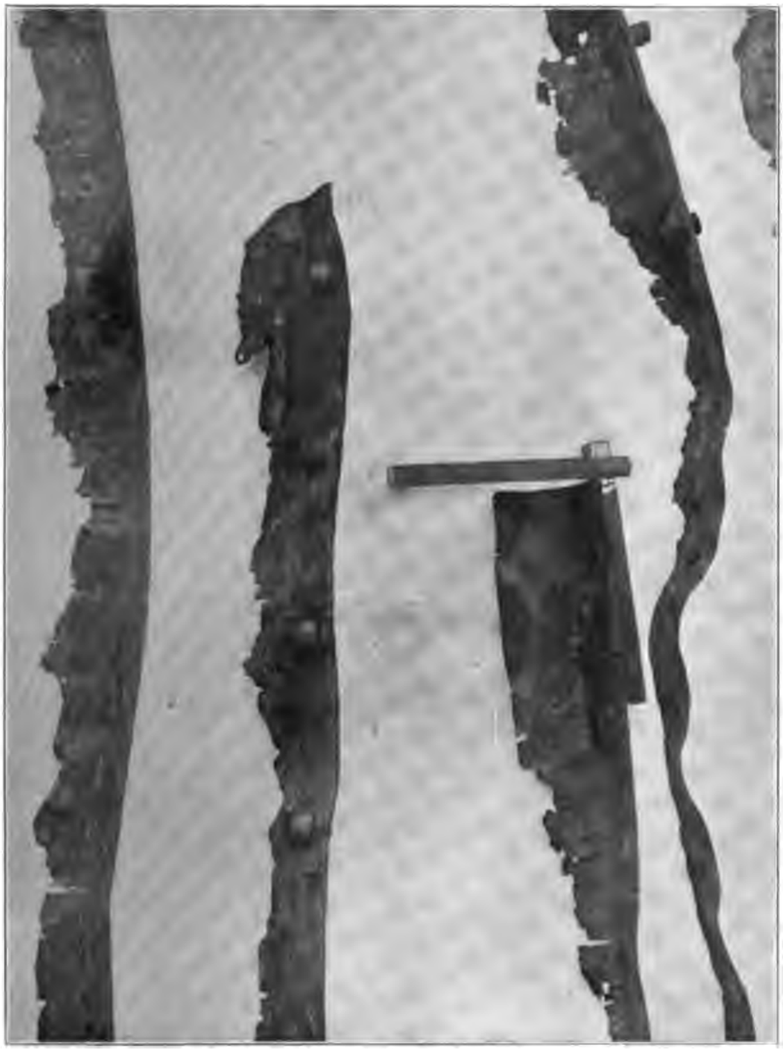
LILLY ON THE SAND-BLAST.



CORRODED ANGLES FROM FOURTH STREET VIADUCT. COLUMBUS, OHIO.

spreading out of the sand to form the larger stream causes it to strike against the sides and then deflect to follow the direction of the hose. One foot in length, or sometimes a little more, cut from this end of the hose occasionally, fitted it for further use. The length of sand hose used varied from 25 to 65 ft., being regulated by the distance of the work from the place where the machine had to be placed. As the machines could not be placed upon scaffolding, in this work, at least 35 ft. of hose were required on nearly all the work, so as to reach from the ground to the floor system, from 16 to 20 ft. above the tracks, and in some places out over the tracks as far as 30 to 40 ft.

The nozzlemen should be men of some judgment and intelligence, so that they will understand how to manage the nozzle to make the blast most effective. In Fig. 4, Plate XVI, a nozzleman is shown in costume ready for work. The helmets worn were of tin, with cloth curtains hanging to the shoulders to keep out the dust, as far as possible. Instead of using wire gauze in the helmet, two pieces of glass were used for the nozzleman to see through, because it excluded the dust more effectually. When frosted over by rebounding sand, the glasses were removed and new ones inserted. After a little experience, a good nozzleman will learn how to hold the nozzle in any given case, varying its distance from the working point according to the manner in which he finds it is operating. Heavy scale requires him to hold the nozzle close, and light cleaning can be done more rapidly by holding it farther away and permitting the blast to spread somewhat and thus cut a wider swath. On moderately hard places about 5 to 6 ins. is the proper distance. To make it clean most rapidly he must also direct the blast so as to cut a swath clean as he goes, passing first in one direction and then in the other, across the member being cleaned, so as to leave no spots to which he must go back and thus waste the force of the blast on clean metal around them. The nozzle should generally be directed so as to strike the surface at a slight inclination from the normal, say 20 to 30° away from the nozzleman, thus blowing the dust and sand away. The cleaning should be carried forward from the nozzlemen, so that the blast will always act upon the exposed edge of scales, rust, or old paint, and, by getting under any loose portions, throw them off without first having to break them up.

The compressed air was supplied by the Union Depot Company, from a compressor with an air cylinder of 14 ins. diameter and a stroke of 12 ins., compressing the air to a gauge pressure of 50 to 60 lbs. The number of strokes was regulated automatically so as to keep the pressure nearly constant. The air was led from the compressor to a large receiver, and then, by a line of 2-in. steel pipe, to a small receiver at the viaduct where the work was to be done. From this receiver (having a capacity of about 9½ cu. ft.) the air was conducted to the sand-blast machines. The pressure at the machines was usually from 30 to 40 lbs. The requisite length of 2-in. pipe varied from about 1 250 to 2 200 ft. The small receiver had a pet-cock in the bottom to let out accumulated water, and it removed much of the moisture from the air used.

The compressed air was paid for by the city, at the rate of 40 and 45 cents per hour for one machine, and 60 cents per hour for two machines in operation. For 18% of the time only one machine was in operation. This made the work cost more, because two machines could have been operated for about one and one-half times what one would cost. A foreman, two nozzlemen and three laborers could operate two machines and dry the sand for them. The foreman was paid 35 cents, nozzlemen 25 cents, and laborers 15 cents during one-half of the time and, after that, 17½ cents per hour.

The sand used was from Lake Erie. An attempt was made to secure rather coarse, clean and sharp sand; but it was at times impossible to do this without some delay, and some of the sand used was too fine and made much dust on account of the silt it contained. The sand was at first dried in two old locomotive ash pans, with old ties for fuel. This required almost constant attendance by one man, to stir it up and keep it from becoming so hot as to make the grains brittle and ineffective.

About May 1st, 1902, the dryer shown in Fig. 1, Plate XVII, was made by fitting a sheet-steel hopper on an old cast-iron stove. The wet sand would not fall through the ¼-in. holes in the lower part of the hopper, but would as soon as dry. The sand was permitted to cool for a few hours before being used, as hot sand caused steam and was likely to choke the small opening in the bottom of the hopper, around the end of the siphon nozzle. The objection to this kind of a dryer is that the fire-pot, being surrounded by sand in contact with it, burns out in a short time. Two fire pots were required in six months' service.

All the viaducts named in Table No. 1 have buckle-plate floor sys-

PLATE XVI.
PAPERS, AM. SOC. C. E.
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LILLY ON THE SAND-BLAST.

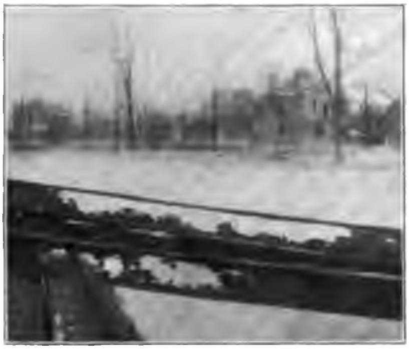

FIG. 1.—CORRODED I-BEAMS FROM FOURTH STREET VIADUCT, COLUMBUS, OHIO.

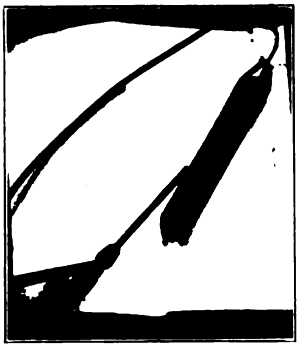

FIG. 2.—SAND-BLAST NOZZLE REDUCER AND BLOWER.

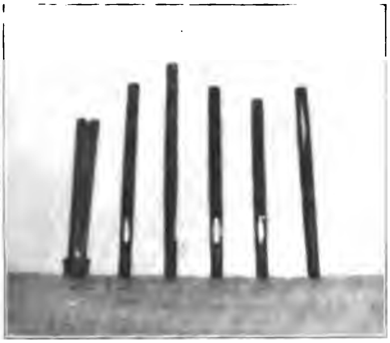

FIG. 3.—WORN-OUT SAND-BLAST NOZZLES.

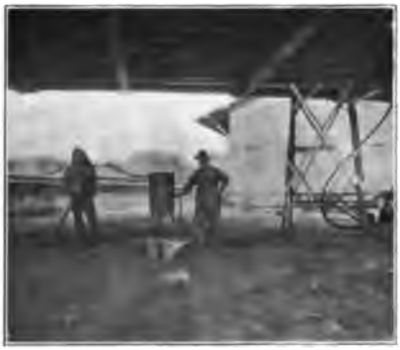

FIG. 4.—SAND-BLAST NOZZLEMAN, IN WORKING COSTUME.

tems, exposing a large amount of steel surface to the action of rust and corrosion. It may be well to state the conditions under which the work of cleaning had to be done, in order to give a better understanding of the items making up the cost. The data here given may then be better analyzed and applied to any other proposed sand-blast cleaning. The first four viaducts named were erected during 1893 and 1894, and all were repainted during August and September, 1896, and none of them had been repainted since that time. High Street Viaduct was erected in the latter part of 1893, repainted in August, 1896, and again in October, 1899. The cleaning done before repainting, in each of these cases, was only hand-cleaning. All appearances indicate that the steel of the Front Street Viaduct over the Pittsburg, Cincinnati, Chicago and St. Louis, and the Cleveland, Cincinnati, Chicago and St. Louis Railways, must have been in better condition than that of any of the other viaducts, and a better quality of paint must have been applied at the time of its erection. This is judged largely from the condition of the portions of the viaducts above the level of the street pavement and protected by it from the direct action of the blast and gases from the locomotives. The portions below the pavement, on all the others, are subjected to greater wear by the locomotive blast on account of their small clearance above the stacks, their clearance above the level of the railroad tracks being only 16.33 to 16.75 ft., while this viaduct has a clearance of 20.33 ft. In cleaning them, therefore, it was impossible to swing any staging below the clearance elevation, in the case of four of them. The Front Street and the Naghten Street Viaducts do not afford sufficient space above the lower surface of the plate girders in which a man can work, and it was necessary to work from movable trestles, about 12 ft. high, made as light as possible, so that they could be moved off the tracks whenever a train or an engine was about to pass, and be replaced and the work continued when the track was clear. This may be seen in the view of the Front Street Viaduct, Fig. 2, Plate XVII.

Under the first three viaducts mentioned in Table No. 1, there are two main tracks and one side track, with a spur track from the middle of the first, making four tracks under the east half of it. The photograph of this viaduct was taken from a point very near the outer rail of the side track and west of the viaduct, and does not show the other tracks.

TABLE No. 1.—Cost, etc., of Sand-Blast Cleaning of Viaducts at Columbus, Ohio.

Location of viaduct.	Cost of labor.	Cost of flagmen.	Cost of compressed air.	Sand Used.		Dryer, sand-blast, scaffolding, etc.	Total cost.	Number of square feet cleaned.	Cost per square foot.	Square feet cleaned with 1 cu. ft. of sand.	Square feet cleaned per hour by one sand-blast.	Average pressure at sand-blast, in pounds per square inch.
				Cubic yards.	Cost.							
Front St., over Little Miami Railroad..	$385.30	$45.15	$139.40	54.00	$78.55	$56.68	$705.08	24 900	$0.0283	17.1	64	85
Naghten St., " " " " ..	140.74	17.85	56.40	28.44	42.41	32.52	289.92	8 000	0.0362	10.4	49	87
Maple " " " " " ..	223.00	11.90	94.80	34.50	58.08	58.70	446.48	17 000	0.0263	18.2	66	85
Front St., over Pittsburg, Cincinnati, Chicago & St. Louis and Cleveland, Cincinnati, Chicago & St. Louis Railways	670.66	....	229.80	92.65	107.48	87.18	1 095.07	63 000	0.0174	25.2	89	80
High St. (South Span)................	951.20	....	319.94	129.91	161.47	122.46	1 555.07	22 600	0.0688	6.1	23	83
Totals and Averages..................	$2 370.90	$74.90	$840.34	339.50	$447.94	$357.54	$4 091.62	135 500	$0.0302	14.8	54	83
Excluding High St. Viaduct............	....	....	....	....	....	....	2 536.55	112 900	0.0225	20.0	74	83

PLATE XVII.
PAPERS, AM. SOC. C. E.
FEBRUARY, 1903.
LILLY ON THE SAND-BLAST.

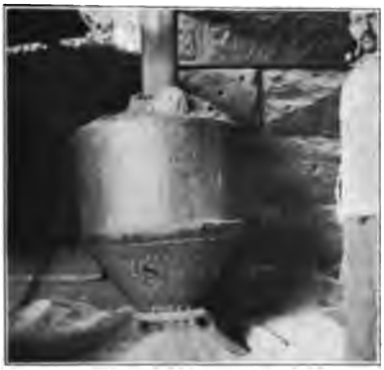

FIG. 1.—SAND DRYER.

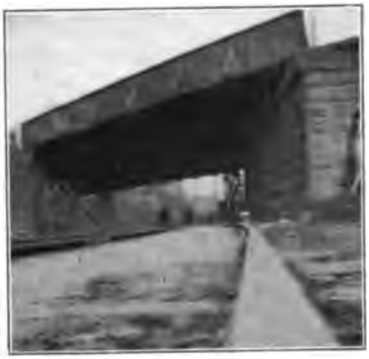

FIG. 2.—FRONT STREET VIADUCT, COLUMBUS, OHIO.

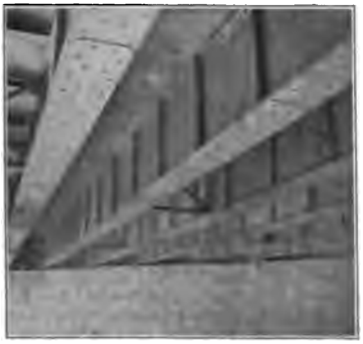

FIG. 3.—PART OF GIRDERS AND BUCKLE-PLATES OF MAPLE STREET VIADUCT, COLUMBUS, OHIO.

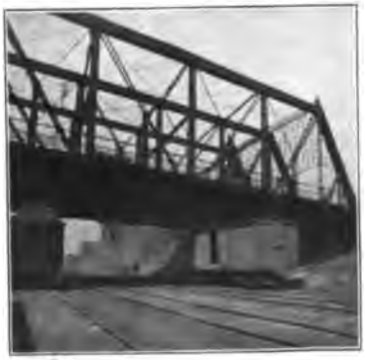

FIG. 4.—PART OF NORTH SPAN OF HIGH STREET VIADUCT, COLUMBUS, OHIO.

The movable trestles were also used, part of the time, in cleaning the cover plates on the bottoms of the girders and the portion of the work along the abutments of the Maple Street Viaduct; but a large portion of the cleaning was done from staging resting upon the lower cover plates and angles of the plate girders. Fig. 3, Plate XVII, shows a portion of the girders and buckle-plate when all except a small portion of the buckle-plate and the web of the girders, where scale can be seen, had been cleaned and given a coat of red lead. Two more coats, of a paint less susceptible to the action of combustion gases, were applied afterward, as on all the viaducts.

To secure the safety of the men while at work on these three viaducts, when using the trestles over the tracks, it was necessary to have flagmen to give warning of the approach of trains, so that the trestles could be removed in time to avoid the danger. On the Maple Street Viaduct flagmen were not needed for so large a proportion of the time as on the other two viaducts. The cost of flagmen alone amounts to about 0.2 cent per square foot on the first two in Table No. 1, and 0.07 cent on the Maple Street Viaduct. The time lost on account of trains and switch engines sometimes amounted to one-fourth of the working time. If there had been no interruption by trains, and if flagmen had not been required, a fair estimate, from approximate calculations, based on records of the time lost each day and the cost of flagmen would reduce the cost fo the work to about the following figures: Front Street Viaduct, 2.3 cents; Naghten Street Viaduct, 3 cents, and Maple Street Viaduct, 2.45 cents, per square foot. Matched flooring screens, fastened with copper nails, were placed immediately over the main tracks and under the floors of these three viaducts, to protect them from the blast from locomotives.

In the Front Street Viaduct, over the Pittsburg, Cincinnati, Chicago and St. Louis and the Cleveland, Cincinnati, Chicago and St. Louis Railways, in which the clearance was 20.33 ft., the staging was supported on iron hangers which reached 2 ft. below the lower flanges of the floor beams. This space, with the 29 ins. more to the buckle-plates, gave room enough for the work, and the staging still gave about 2 ft. more clearance than the High Street Viaduct, just east of it and over the same tracks. Fig. 4, Plate XVII, shows part of the north span of this viaduct, over the Cleveland, Cincinnati, Chicago and St. Louis Railway tracks. The portion of the three heavy trusses above the pavement was in very fair condition, and it was not thought necessary to clean it with the sand-blast. This saved the cleaning of 36 000 sq. ft. of metal surface on this viaduct, while, on the others, practically all was cleaned. A portion of this viaduct, shown in Fig. 4, Plate XVI, is not over the railroad tracks, and was not affected as seriously as the remainder of the floor system. Some of the paint was still good, and it was not all taken off. This, together with the fact that there was not much interruption to the work, made the cost of cleaning, on this viaduct, less than on any other, all the others being much affected with rust, scale and corrosion upon nearly all parts of them, even above the level of the pavement, where protected from the direct action of the gases.

The south span of the High Street Viaduct, the portion already cleaned, is over the main freight and passenger tracks, and yard engines pass under it frequently. The other spans can be cleaned for very much less than this one. It has been estimated by men who are in the employ of the Pennsylvania Railway Company that an average of from 250 to 300 engines pass under this span every 24 hours. The girders and buckle-plates were in very bad condition, and very heavy and exceedingly firm scale had been formed over large portions of them. This scale was firmly cemented to the steel by the rust and carbonates which had formed. As a consequence, the sand-blast did not blow off much of it, nor did it work under the scale and throw it off, as on the other viaducts. Therefore, it cost nearly twice as much as the highest of the others, and nearly four times as much per square foot as the large Front Street Viaduct. The floor system is similar to that of the Maple Street Viaduct, the pavement being supported by seventeen plate girders. Immediately east of this is the structure under the roadway to the Union Station, also having seventeen plate girders. The distance over both is about 165 ft., and this, with the girders extending 3.5 ft. below the floor, causes the smoke to hang a long time between the girders after an engine has passed beneath. Often, it does not clear away before another engine comes along and again fills all the spaces with dense smoke. The smoke, and the dust from the sand-blast work, therefore, caused a great deal of trouble. It was very difficult, and part of the time impossible, to get nozzlemen to keep both blasts in operation. To get rid of the smoke and dust, an electric fan was tried for a short time, it being placed near the abutment between the girders where the work was progressing. This kept the smoke from rising, and cleared away the dust quite well; but the bearings were injured very much by the dust and fine sand. Then the blower shown in Fig. 2, Plate XVI, was made. This was connected with the air pipe by a ½-in. rubber hose, and a jet of compressed air, passing through an opening of about $\frac{1}{32}$ in., and into and through a section of 5-in. sheet-iron pipe, about 2 ft. long, set up a current of air, which, being directed along between the girders, was quite effective. One of these was made for each sand-blast, and they were used for a considerable portion of the time. Smoke and dust, however, would gather behind the blower and be drawn through it at times, and it was not a complete success. It was effective for a distance of about 20 ft.

Another cause of the high cost of this work was the low pressure secured at the sand-blast machine during much of the time. The operation of the blowers tended to reduce it, and the compressor was worked beyond its intended capacity, and was not at the time doing as good work as earlier. The average pressure, at this viaduct, as stated in Table No. 1, is partly an estimate, as the gauge was broken and for a portion of the time was not in use. When at 30 lbs. or less, the sand-blast was very slow in cutting the scale here encountered; but when at 38 to 40 lbs., it was much more efficient. Occasionally, when only one blast was in operation for a short time, the pressure would run up to 45 lbs., and then the effect was still better.

From the experience in sand-blast cleaning here given it may be stated safely that, for heavy scale and corrosion, in situations such as this High Street Viaduct, a pressure of from 35 to 45 lbs. per square inch is not any too high. On the other hand, very efficient work is done at a pressure of about 25 lbs., where only light scale, rust spots and disintegrating paint are to be cleaned off. The labor costs approximately twice as much as the power, and increase of power is advisable where needed.

On all the cleaning done, the bright surface of the steel, having almost the appearance of frosted silver, was exposed to view by the removal of every vestige of rust, scale and old paint. The pitted portions, with a little more brushing, were as well covered with the paint as the others, and, after one year, it still holds on them as firmly, to all appearances, as when it first dried, after being put on.

The paint was applied very soon after the sand-blast, and sometimes curtains of heavy muslin were stretched between the painters and the sand-blast to prevent the dust and sand from interfering with the painting. All surfaces cleaned were painted before night, and rarely was it necessary for the painters to work more than half an hour after the sand-blast was discontinued for the day. It is best to work with the wind, so that it will carry the dust and sand away from the painters and nozzlemen.

Some records of actual results are shown in Table No, 2, both in the ordinary work of cleaning, and on tests in which an accurate account was taken for all the data presented therein. In some of these records there are omissions because all the elements were not noted. The long-time records give only the surface cleaned, and not the sand used or the horse-power necessary; and the two, showing results as to the whole work, are included for the sake of comparison. In these two are given some other results of calculations, from known quantities and records, which represent rates for one sand-blast, although two were running about 82% of the time. The number of hours stated is obtained by adding together the number of hours run by each machine. The tests of October 16th and 31st, 1902, were made in order to determine the relative effectiveness of nozzles of different diameters, from ¼ to ¾-in. in size. The sizes of pipe given are the nominal sizes of gas pipe, with "Ex. H." added where extra heavy gas pipe was used, which, of course, is smaller in interior diameter than standard gas pipe. The last one noted was with a nozzle (Fig. 3, Plate XVI), made from three ½-in. gas pipes, one end of each being inserted in a 1¼ × 1-in. bushing, and babbitt metal poured in to secure them there. While only made for an experiment, this nozzle gave very good results, it having the highest rate of cleaning, in square feet per hour. It used considerable sand, about the same as the ¾-in. pipe, but cleaned nearly one-half more.

All these tests were made on the High Street Viaduct, where, for all of them, the corrosion was, as nearly as possible, of the same character. The rates of cleaning are low, because, on this viaduct, the scale was so hard. These tests of nozzles were made with a sand hose 65 ft. in length. All the nozzles for these eight tests were 12 ins. long. It will be seen from the results that the ½-in. extra heavy pipe, which is ⅝ in. when worn out, is about the proper size for this kind of work.

TABLE No. 2.—DATA AS TO THE OPERATION OF THE SAND-BLAST; AND TESTS OF NOZZLES OF DIFFERENT DIAMETERS, AT COLUMBUS, OHIO.

Date.	DURATION.		Nominal size of gas pipe nozzle.	AIR PRESSURE.		Cubic feet of free air per minute.	Horse-power required.	Cubic feet of sand used.	Area cleaned, in square feet.	Square feet cleaned per cubic foot of sand.	RATES PER HOUR.		Remarks.
	Hours.	Minutes.		At compressor.	At sand-blast.						Cubic feet of sand.	Square feet cleaned.	
1899. Sept. 27	....	29	½"	..	35	170	20.4	1.52	110	72.5	3.14	237.6	Pittsburg, Cincinnati, Chicago and St. Louis Railway work.
1901. Nov. 14	....	55	½" Ex. H.	50	35	170	20.4	6.60	144	21.8	7.20	157.1	Plate girder, considerably rusted.
" 16	....	26	½" Ex. H.	50	36	...	....	2.20	77	35.0	5.10	177.7	Plate girder, paint nearly destroyed.
" 14	4	45	½" Ex. H.	50	35	170	20.4	....	875	....	....	79.0	Plate girder (includes lost time).
" 16	3	..	½" Ex. H.	50	36	...	....	....	822	....	....	107.3	Plate girder, paint nearly destroyed (includes lost time).
" 18	7	50	½" Ex. H.	50	36	...	....	....	655	....	....	93.6	Plate girder, paint nearly destroyed (includes lost time).
" 19	7	30	½" Ex. H.	50	35	...	....	....	825	....	....	110.0	Plate girder, paint nearly destroyed (includes lost time).
" 20	7	30	½" Ex. H.	40	35	...	....	....	1 237	....	....	164.0	About 10% of paint good and not removed (includes lost time).
Dec. 7	13	30	½" Ex. H.	48	33	...	....	....	1 000	....	....	74.1	Floor system over railroad tracks (includes lost time).
Nov. 14th, 1901, to Aug. 13th, 1902	1 519	..	½" Ex. H.	..	33	...	....	5 658.9	112 900	20.0	3.78	74.8	First four viaducts in Table No. 1.
1903. Aug. to Nov.	990	..	[illegible]" Ex. H.	..	33	...	....	3 507.6	22 600	6.4	3.54	22.8	High Street Viaduct, see Table No. 1.
Oct. 16	....	18	[illegible]" Ex. H.	55	37	156	18.7	1.40	11.80	8.4	4.67	39.33	High Street Viaduct, test run.
" 16	....	24	[illegible]"	55	37	140	16.8	1.31	6.65	5.1	3.28	16.63	High Street Viaduct, test run.
" 16	....	27½	[illegible]"	55	39	108	13.0	1.20	2.42	2.0	2.62	5.28	High Street Viaduct, test run.
" 20	....	27	[illegible]" Ex. H.	..	35	...	....	3.30	18.70	5.4	7.67	41.60	High Street Viaduct (another blast running).
" 21	....	7½	[illegible]"	55	40	200	24.0	1.10	4.25	3.9	9.10	35.20	High Street Viaduct, test run.
" 21	....	18	[illegible]" Ex. H.	55	41	170	20.4	2.20	14.00	6.4	7.33	46.67	High Street Viaduct, test run.
" 21	....	9	[illegible]"	55	42	156	18.7	1.10	6.60	6.0	7.33	44.00	High Street Viaduct, test run.
" 21	....	24	[illegible]"	55	43	180	15.6	1.00	4.75	4.7	2.50	11.88	High Street Viaduct, test run.
" 21	....	7	[illegible]"	55	41	176	21.1	1.10	6.60	5.4	9.48	51.40	High Street Viaduct, test run.

Improvements can certainly be made in this apparatus. Some of the appliances were made as experiments, and are rather crude. One observation may be made which will occur to all, that more sand-blasts might be added with advantage, if sufficient power to run them were provided. The work at Columbus was limited to two machines, on account of the small capacity of the compressor. Perhaps a larger pipe to convey the air would have added to the pressure at the machines, and to the effectiveness of the sand-blast. For ordinary cleaning of bridges and other structures, not subjected to such hard treatment as viaducts situated where much exposed to the blast and gases from locomotives, it is safe to say that, with a more perfect equipment, sand-blast cleaning can be done at from 1¼ to 2 cents per square foot. The advantages anticipated for this kind of cleaning, especially where almost a necessity, because nothing else will do the work thoroughly, are to be gained by a careful inspection at intervals after it is done, and the repainting, with ordinary, good hand-cleaning, before the paint has been worn off so as to set up the vigorous rusting process which comes when air and moisture get to the metal. In such locations as the viaducts in Columbus it seems to be the only thing that will do the work. For future construction in similar locations let every engineer beware of the use of steel exposed to locomotive blasts, as these will wear out any paint. The life of those structures already in existence, and others which may be built in the future, should be extended as long as possible by the use of the best means that can be commanded.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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THE FILTRATION WORKS OF THE EAST JERSEY WATER COMPANY, AT LITTLE FALLS, NEW JERSEY.

By George W. Fuller, Assoc. M. Am. Soc. C. E.

To be Presented April 1st, 1903.

Historical.

The East Jersey Water Company, in 1897, commenced the development of a new source of supply from the Passaic River, at Little Falls, N. J., about 5 miles above Paterson. The pumping station, which was completed in the autumn of 1899, has a capacity of 75 000 000 galls. daily. It is a combination water- and steam-power plant, the pumps being placed between the turbines and steam engines, and connected so that either water or steam power, or both, may be used.

At present, an average daily quantity of about 50 000 000 galls. of water is pumped at this station. Approximately, this quantity has been pumped regularly since November, 1899, and supplied to cities having an aggregate population of about 450 000. About 30 000 000 galls. daily are supplied to Jersey City, in accordance with a temporary contract with the Water Company which terminates at the end of 1903, following the completion of the new gravity water supply now

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Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers with discussion in full will be published in *Transactions*.

being constructed for that city on the Rockaway River, near Boonton, N. J. About 15 000 000 galls. daily are supplied from this station to the cities of Paterson and Passaic. At the close of the Jersey City contract, filtered water from Little Falls will be supplied, to several towns and water companies, through the conduit now used to deliver river water to Jersey City. Among these consumers are Montclair, West Orange and Glen Ridge, which now receive their supply from the surplus of the Pequannock system, in accordance with arrangements made by the East Jersey Water Company with the City of Newark. After the present year, in the neighborhood of 25 000 000 galls. of filtered water daily will probably be furnished from Little Falls.

The water-shed of the Passaic River, at Little Falls, has an area of 772 sq. miles. A large part of two important tributaries of the Passaic is already appropriated for municipal supplies, namely, 63 sq. miles of drainage area of the Pequannock River, which is the source of supply of the City of Newark, and 118 sq. miles on the Rockaway River, above the intake for the works now being built for Jersey City. Some of the more important features of interest in connection with the Passaic water-shed are indicated in Fig. 1.

There are no towns or cities discharging sewage into the Passaic River within some 20 miles of the intake at Little Falls. The only places on the water-shed having sewerage systems are Suffern and Summit, the sewage of the latter being filtered before it reaches the river. There are, however, quite a number of towns and small cities, including Chatham, Madison, Morristown, Boonton and Dover, where there are public water supplies, and where some sewage may reach the stream indirectly, especially following heavy rains.

In its sanitary character the water of the Passaic River at Little Falls is ordinarily very satisfactory, as is shown by numerous analyses and by the typhoid-fever records of the communities which have been supplied with that water during the past three years. The average annual death rate from typhoid fever during the past three years, in Jersey City, Paterson, Bayonne and Passaic, is about 20 per 100 000 inhabitants, and in no case has it exceeded 23 for a single year.

The Passaic River water at Little Falls is not muddy, comparatively speaking, although, after heavy freshets, it carries from 25 to 100 parts per million of suspended matter. At times the water is very noticeably colored, due to dissolved vegetable matter coming from

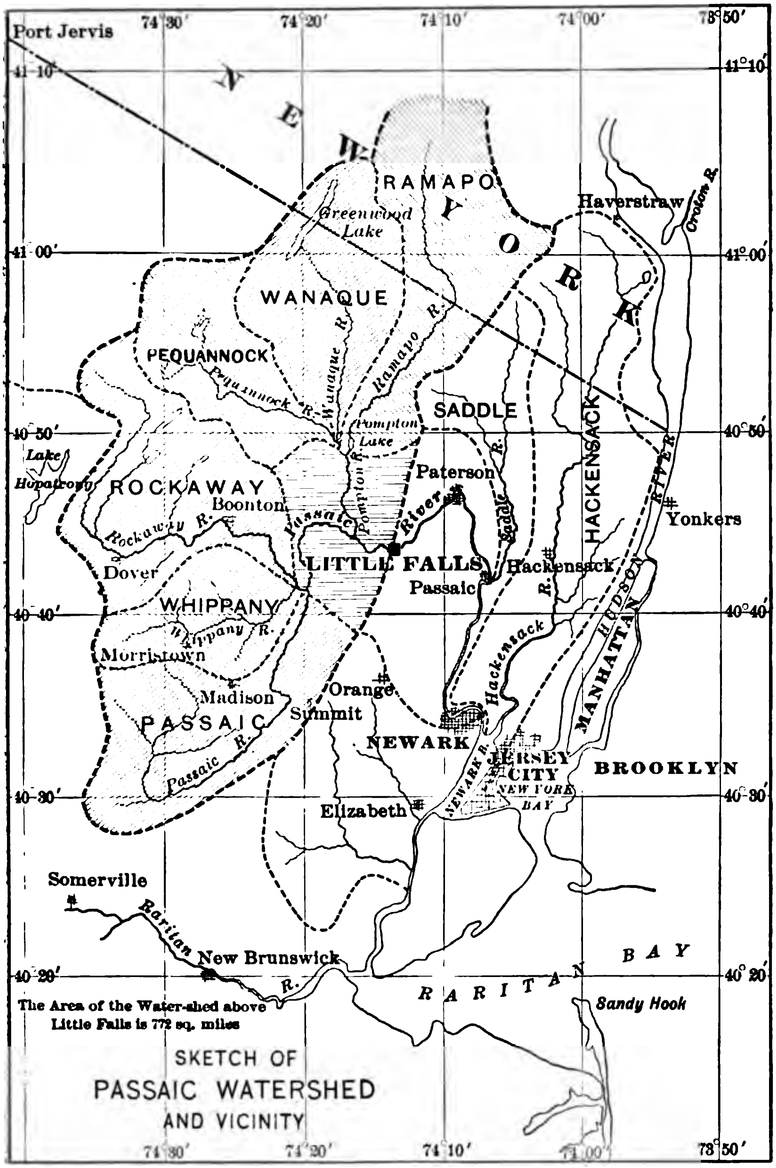

Port Jervis
74°30′
74°20′
74°10′
74°00′
73°50′
41°10′
41°00′
40°50′
40°40′
40°30′
40°20′
NEW YORK
RAMAPO
Greenwood Lake
WANAQUE
Wanaque R.
Ramapo R.
PEQUANNOCK
Pequannock R.
Pompton Lake
Pompton R.
SADDLE
Saddle R.
Paterson
Lake Hopatcong
ROCKAWAY
Rockaway R.
Boonton
Passaic River
LITTLE FALLS
Passaic
Hackensack
Hackensack R.
HACKENSACK
Dover
WHIPPANY
Whippany R.
Morristown
Madison
Orange
Summit
PASSAIC
Passaic R.
NEWARK
Newark R.
JERSEY CITY
NEW YORK BAY
Elizabeth
Haverstraw
Croton R.
Yonkers
HUDSON RIVER
MANHATTAN
BROOKLYN
Somerville
Raritan R.
New Brunswick
RARITAN BAY
Sandy Hook
The Area of the Water-shed above Little Falls is 772 sq. miles
SKETCH OF PASSAIC WATERSHED AND VICINITY

FIG. 1.

several large swamps situated on the upper portions of the drainage area. Frequently, the water contains quite large amounts of amorphous matter, consisting principally of finely divided organic material. Much of this seems to come from the bottom of the stream, as the water flows for a few miles through the Great Piece Meadows, just above the intake, where the river has very little slope and where deposited sediment on the bottom is stirred up by carp and other fish. This finely divided amorphous matter, together with the color which appears in the water, gives it at times what might be called a "dirty" appearance, and causes it to be less desirable for domestic use than the analyses indicate.

With the view of making the water thoroughly satisfactory in appearance, and to guard against the effect of the accidental pollution which may be possible occasionally, the Water Company investigated the feasibility of filtration works. A preliminary report on the subject was made by the writer in May, 1900.

Before considering this matter in detail, it will be well to give a general description of the pumping station and immediate vicinity. The pumping station was described in *Engineering News* of August 3d, 1899, in which the principal details may be found. In brief, it may be said that the river water, for both power and water-supply purposes, is conveyed from the river above the Beattie Dam to the intake gate-house near the pumping station through a head-race canal, 1 400 ft. in length and 60 ft. in width. It terminates in a fore-bay, at the side of which is a spillway, and at the end are the penstocks and other conduits leading to the turbine wheels and to the pumps.

The elevation of the water in the head-race canal is normally about 157. In the river below it averages about 122, giving, ordinarily, a fall of about 35 ft. for power purposes. The floor of the pumping station is at Elevation 132, which is also the elevation of the suction chamber of the pumps. To the north of the pumping station is a cliff of trap rock overlying brown stone, the elevation of the surface being in the neighborhood of 180.

The site of the pumping station and power-house was reclaimed from the original river-bed. As will be seen from Fig. 2, a plan of the station and grounds, the river turns to the north just below, leaving an area of less than 2 acres between the river and the force mains, the elevation of the surface of which was in the neighborhood of 130.

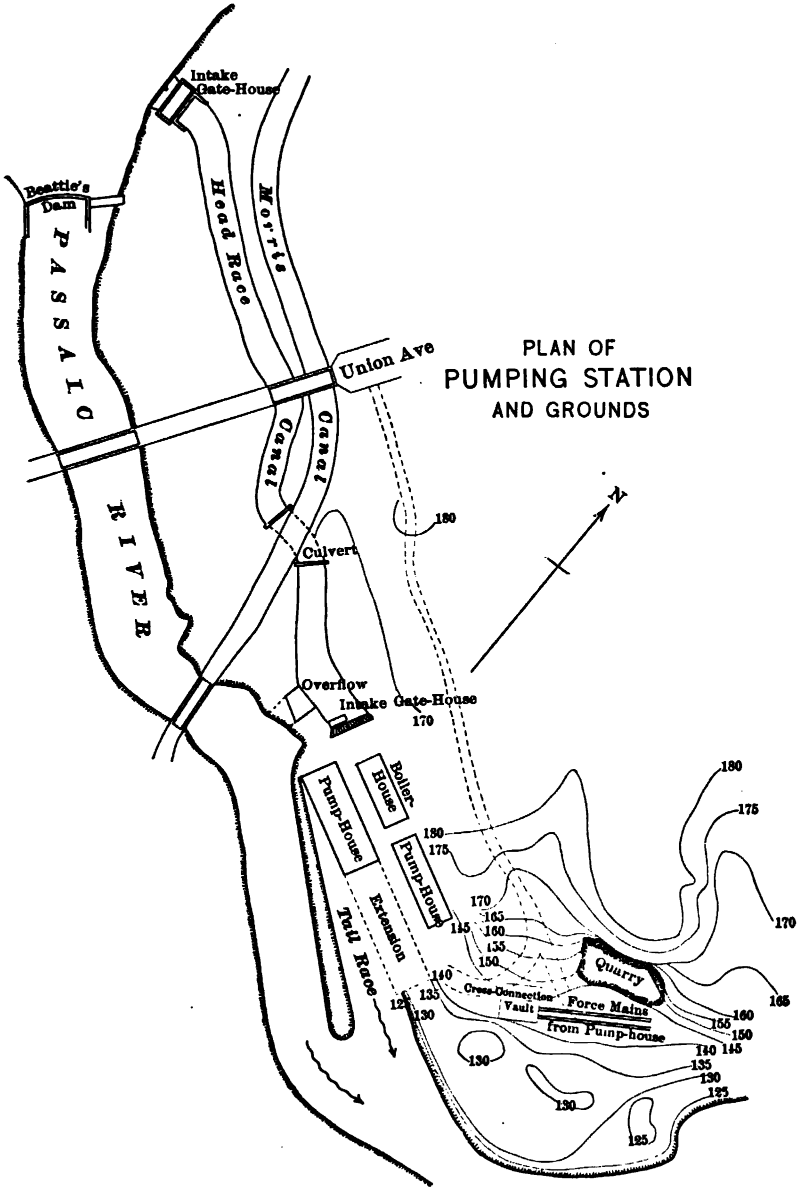

PLAN OF
PUMPING STATION
AND GROUNDS
Intake Gate-House
Beattie's Dam
PASSAIC RIVER
Head Race
Morris Canal
Canal
Union Ave
N
Culvert
Overflow
Intake Gate-House
Boiler-House
Pump-House
Pump-House
Extension
Tail Race
Quarry
Cross-Connection Vault
Force Mains from Pump-house
180
175
170
165
160
155
150
145
140
135
130
125

Fig. 2.

It was recommended that the filtration works be of the American, or mechanical, type, partly on account of the great desirability of removing the high amount of color which the river water possesses at times, and especially on grounds of economy. It was possible to construct a mechanical filter plant on the small area of ground below the pumping station, through which water might pass by gravity from the head-race canal and back to the suction of the main pumps. If a sand-filter plant had been installed, it would have involved the expense of an additional pumping station to lift the river water to a suitable site upon the cliff above.

The Water Company, in June, 1900, requested the New York Filter Manufacturing Company and the Continental Filter Company, shortly afterward consolidated as the New York Continental Jewell Filtration Company, to submit outline plans and general estimates of cost for this project. These were submitted to the Water Company in September, 1900, and were referred to the writer, who was requested to supervise for the Water Company the preparation of detailed plans by the Filtration Company, and also to prepare specifications. It is gratifying to record that the Water Company instructed the writer not to spare expense in making the plant capable of giving thoroughly efficient service. Mr. Charles L. Parmelee, Chief Engineer of the Filtration Company, had the immediate charge of the preparation of the plans. Upon their construction features the writer had the assistance of W. B. Fuller, M. Am. Soc. C. E., who, later, was appointed by the Water Company as Resident Engineer in charge of the construction work. The entire project was designed and built under the direction of J. Waldo Smith, M. Am. Soc. C. E., Chief Engineer and Superintendent of the East Jersey Water Company. With the exception of the machinery and the operating devices, which were designed by the Filtration Company, the design of this plant was the result of numerous conferences and discussions between the representatives of the Water Company and the Filtration Company.

These works, with few exceptions, were built by contract. All excavation and masonry work in the coagulating basin and clear-water basin, grading, etc., was done by the T. A. Gillespie Company, of New York and Pittsburg; the filter tanks and the entire superstructure were built by Mr. Joseph Sharpe, of Paterson sub-contractor under he Gillespie Company; and the entire equipment of the filters, includ-

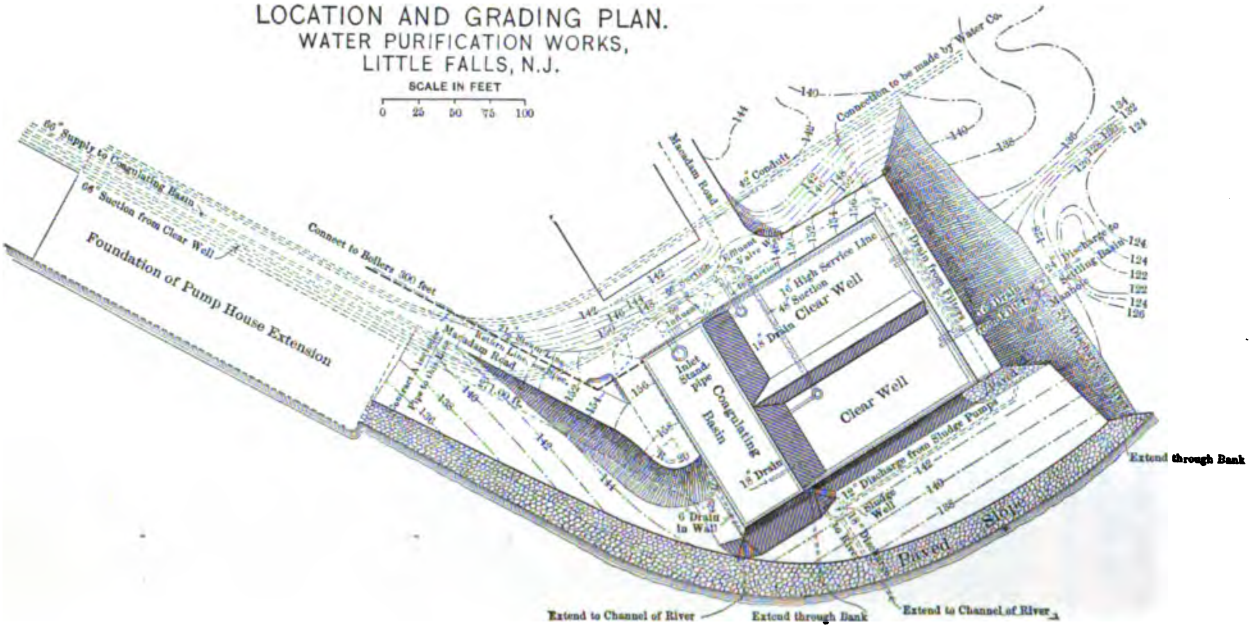

LOCATION AND GRADING PLAN.
WATER PURIFICATION WORKS,
LITTLE FALLS, N.J.
SCALE IN FEET
0 25 50 75 100
66" Supply to Coagulating Basin
66" Suction from Clear Well
Foundation of Pump House Extension
Connect to Boilers 300 feet
Macadam Road
Return Line
42" Conduit
Connection to be made by Water Co.
Effluent Valve
Influent
Inlet Stand pipe
Coagulating Basin
16" High Service Line
48" Suction
Clear Well
18" Drain
Clear Well
Drain from Filters
Sludge Pumps
12" Discharge from Sludge Pumps
Sludge Well
6" Drain in Wall
Discharge to Settling Basin
Manhole
Paved Slope
Extend to Channel of River
Extend through Bank
Extend to Channel of River
Extend through Bank
144
142
140
138
136
134
132
126
124
122
146
150
152
154
156

FIG. 3.

ing piping, valves, strainer systems, machinery and devices for applying the coagulant and operating the filters, was furnished and erected by the Filtration Company.

Construction work was begun early in April, 1901, and at the end of that year all masonry work, pipes within the walls of the coagulating basin and the clear-water basin, the filter tanks, and the floor of the superstructure, were completed. The walls of the superstructure were barely started. The completion of the buildings proceeded very slowly, due to several interruptions by strikes, etc., and it was not until May, 1902, that the Filtration Company commenced the equipment of the filters. The latter was practically completed by August 1st, 1902; but, owing to delays in securing filter sand, the plant was not placed in service until September 4th, 1902. Since that date the filters in the north wing have been in service regularly, and no unfiltered water has been delivered to consumers in Paterson or Passaic.

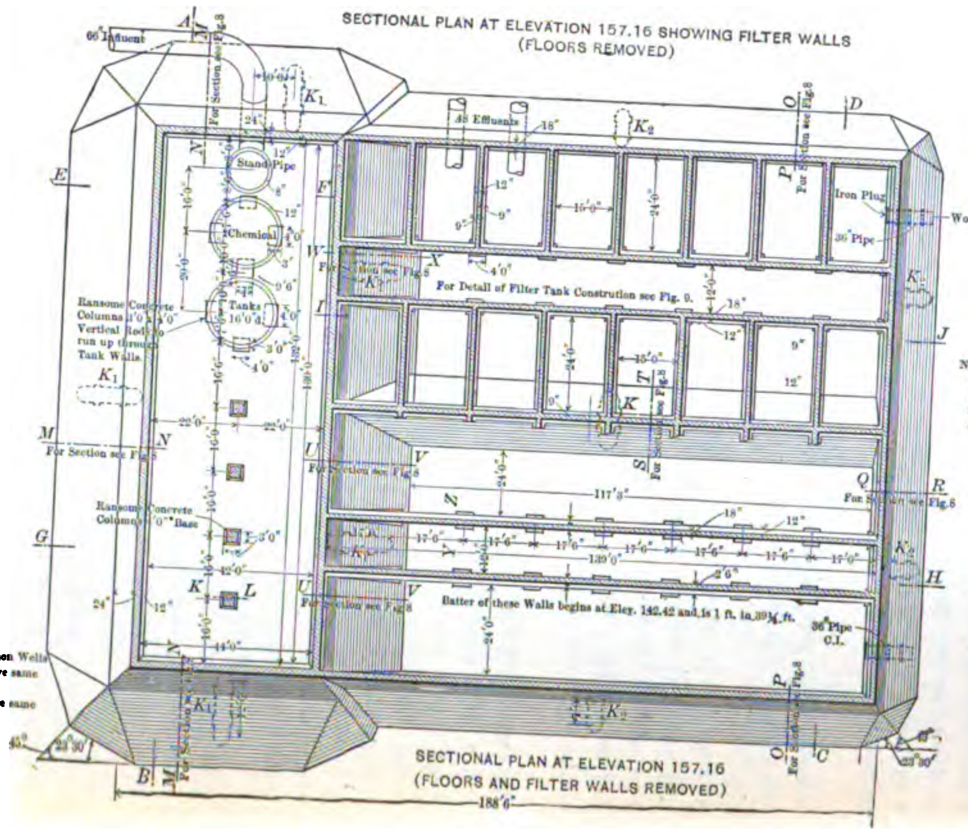
The filters in the south wing have not been placed in service, and will not be until after the termination of the temporary contract with Jersey City.

GENERAL DESCRIPTION OF THE FILTRATION WORKS.

These filtration works, which have a nominal net capacity of 32 000 000 galls. daily, and are capable, at least for short periods, of yielding 48 000 000 galls. daily, occupy an area of 178 x 219 ft., measured on the outside lines of the foundation walls. The structures are of concrete, with the foundations upon rock at an average elevation of 114. As the flow line in the coagulating basin and in the filters is but a little less than that in the head-race canal (157), it is seen that the structures are relatively very deep, owing to the peculiarities of the site. Views of the works are shown in Plate XVIII.

At the west end is the coagulating and subsiding basin, 130 ft. long, 42 ft. wide and 43 ft. deep on inside lines, having a capacity of about 1 750 000 galls.

At the east end the lower portion of the structure contains a clear-water basin in two compartments. Each, on an average, is 124 ft. long, 58 ft. wide and 29 ft. deep to the maximum flow line for the filtered water. The total capacity of the clear-water basin is about 3 500 000 galls. Fig. 3 is a general plan of the coagulating basin and clear-water basin.


SECTIONAL PLAN AT ELEVATION 157.16 SHOWING FILTER WALLS
(FLOORS REMOVED)
66" Influent
For Section see Fig.8
Stand Pipe
Chemical
Tanks 16'0"d.
Ransome Concrete Columns 4'0"×4'0" Vertical Rods to run up through Tank Walls
Ransome Concrete Columns 4'0" Base
48" Effluents
For Detail of Filter Tank Construction see Fig. 9.
117'3"
139'0"
Batter of these Walls begins at Elev. 142.42 and is 1 ft. in 39½ ft.
36" Pipe C.I.
Iron Plug
36" Pipe
Wooden Plug
For Section see Fig.6
For Section see Fig.8
A
B
C
D
E
F
G
H
I
J
K
K₁
K₂
L
M
N
O
P
Q
R
S
T
U
V
W
X
Y
Z
45°
23°30'
188'6"
SECTIONAL PLAN AT ELEVATION 157.16
(FLOORS AND FILTER WALLS REMOVED)

NOTE:
K-K are Expansion Wells
All K₁ Wells have same dimensions.
All K₂ Wells have same dimensions.

NOTE:
The Outer Toes of all Walls and Posts are shown approximately only.
Their exact position depends upon the elevation of the Rock.

GENERAL PLAN OF SUBSTRUCTURE

FIG. 4.

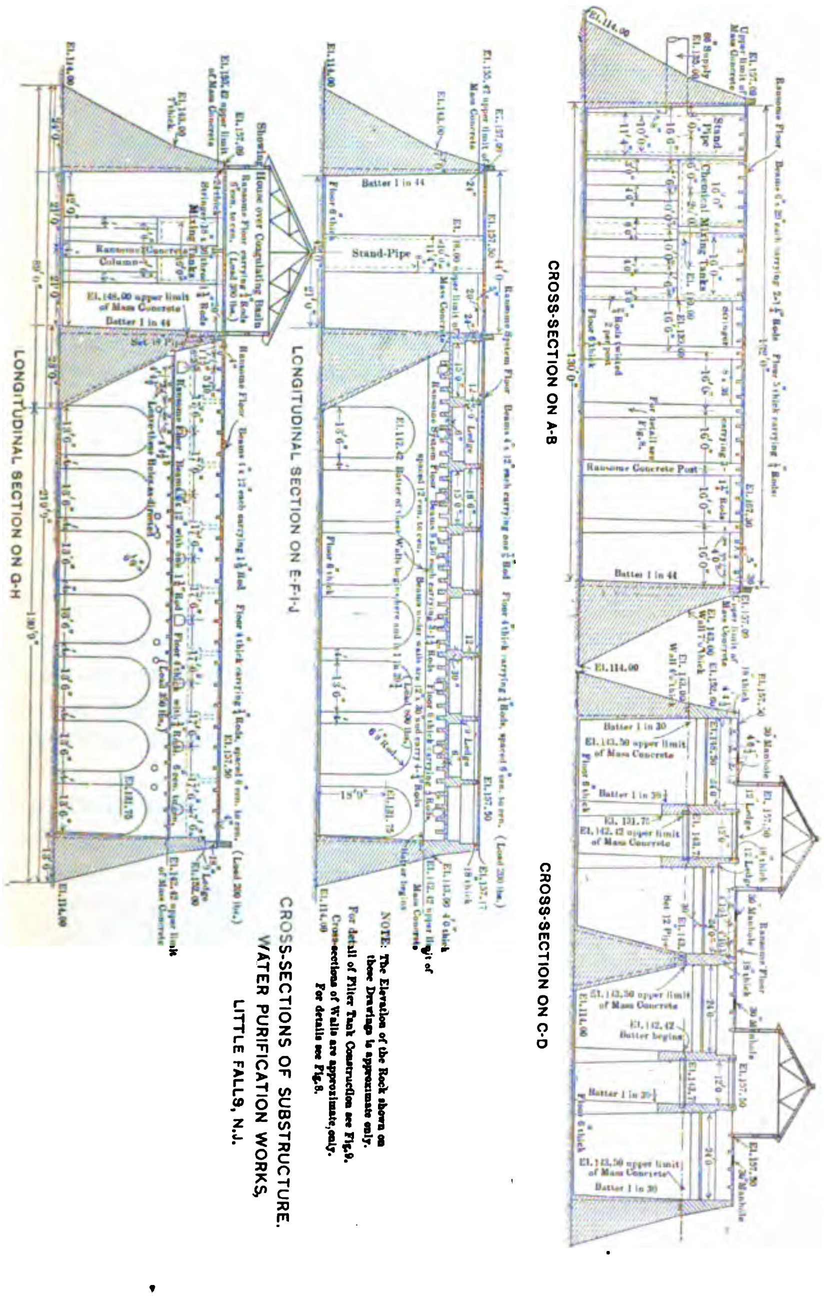
Above the clear-water basin there are thirty-two rectangular concrete filter tanks, 24 x 15 ft., and 8 ft. deep, arranged in four rows of eight filters each. The total area of filtering surface is 11 520 sq. ft. Between each pair of rows of filters there is a pipe gallery, in which the main pipes, with branches to the adjoining filters, are placed. This gallery is about 12 ft. wide and 13.5 ft. high, inside. The ends of the filter tanks form the upper portion of the walls of the galleries. The lower portion is formed by walls which extend to the bottom of the clear-water basin, and form a support for the filter floors. The lower portion of these walls is arched out. A sectional plan and cross-sections of the substructure are shown in Figs. 4 and 5.

Over each pipe gallery there is a platform, at a level slightly above that of the water in the filter tanks, and on which the attendants stand when operating the filters. Over each of these platforms, and extending for a width of about 6 ft. on either side, is a building. These two buildings, each about 140 x 30 ft., are called the filter houses, and form two wings of the main building, with which they connect. The remaining portion of the filters is covered with a flat concrete roof with a manhole over each filter, through which materials may be added or removed.

The coagulating basin is covered with a flat concrete roof, which forms the floor of the main building. This building is 132 x 46 ft., and contains the machinery-room for the rotary blowers, pumps and devices for applying coagulant, storage for the same, and also the laboratories, offices, tool-room, wash-rooms, lockers, etc. Figs. 6 and 7 show a plan and section of the buildings.

All machinery is operated by electric motors, the current for which, as well as for the electric lights, is furnished by generators located in the main pump-house.

River water is taken from the head-race canal, and is delivered to the filtration works through a 66-in. steel main discharging into a concrete stand-pipe, 10 ft. in diameter, located at the north end of the coagulating basin. In this stand-pipe the water is treated with a solution of coagulant, and, after thorough mixing by the natural agitation in the stand-pipe, it passes from the bottom of the same into the coagulating basin and thence to the south end, where, near the surface, it is collected in a perforated pipe, through which it passes to the filters. It is possible to by-pass the coagulating basin,



NOTE: The Elevation of the Rock shown on these Drawings is approximate only.
For detail of Filter Tank Construction see Fig.9.
Cross-sections of Walls are approximate, only.
For details see Fig.8.

CROSS-SECTIONS OF SUBSTRUCTURE.
WATER PURIFICATION WORKS,
LITTLE FALLS, N.J.

FIG. 5.

and deliver the water from the upper portion of the stand-pipe through a pipe connecting with the main inlet pipes to the filters. After passing through the filters the water enters the clear-water basin, from which it flows through a 66-in. steel suction main, encased in concrete and leading to the main pumps. Branch suction pipes extend from the sump in either compartment of the clear-water basin, with necessary valves in an effluent-valve well, located outside the basin where the branches join the main line. Filtered water from the entire plant may be taken from either compartment independently of the other.

Necessary facilities are also provided for cleaning out the coagulating basin, including a pump located in a sludge well to the south of the basin. Arrangements are made by which at times of low water, if need be, the sediment removed from the basin, as well as that from the discharged wash-water, may be settled out in a catch-basin to the east of the filter plant. The main features of the outside piping are shown in Fig. 3.

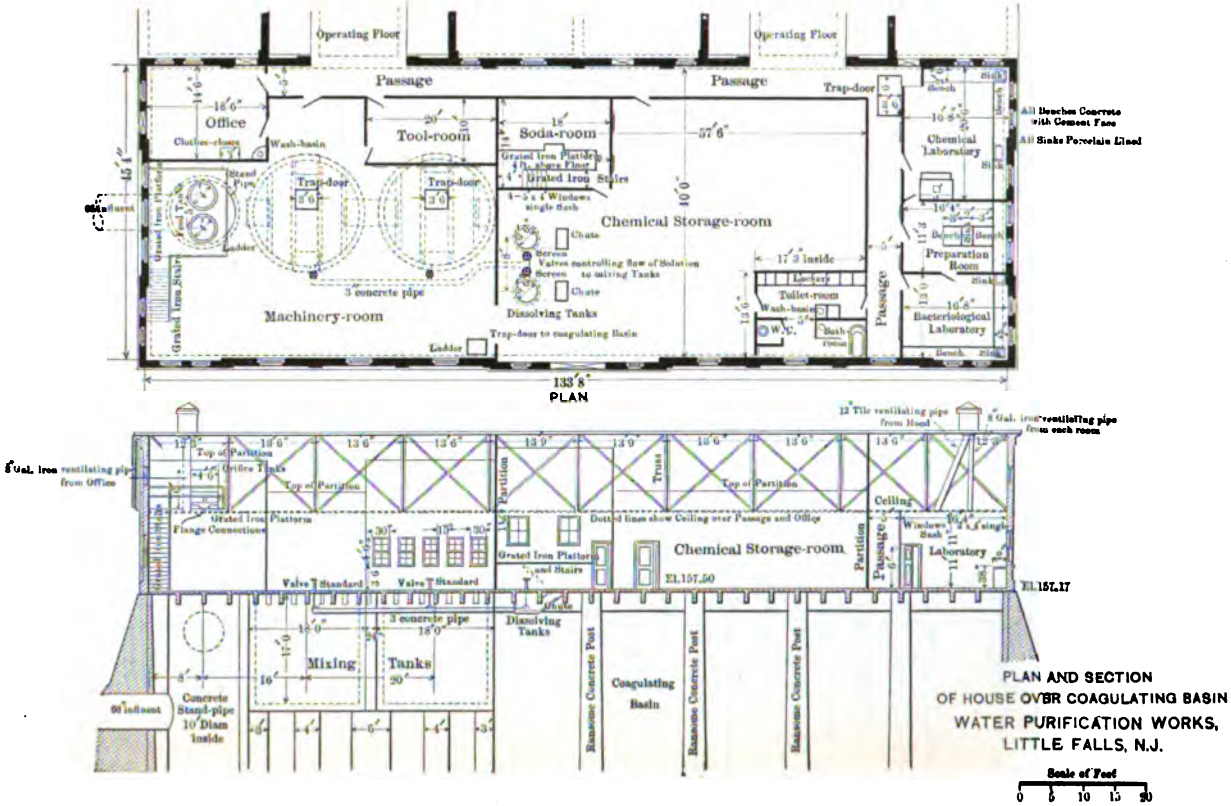
General Features of Construction.

The coagulating basin and clear-water basin are of concrete. Reinforced concrete, after the Ransome system, was used for the construction of the filter tanks, all floors and walls of the houses, and the roof of the filter tanks. No wood was used about the buildings, except in the doors and windows.

The mass concrete in the main walls of the substructure was mixed in the proportion of 1 : 3 : 7. Atlas cement, exclusively, was used for this portion of the work. The gravel and broken stone were graded with much care, the general range in size being from ¼ in. to 3 ins. in diameter. The concrete was laid unusually wet. On the inside of the principal walls there is a facing of rich concrete mixed in the proportions of 1 : 1½ : 3. Typical sections of the main walls are shown in Fig. 8.

In the main walls, as shown by dotted lines on Fig. 4, there were left seven expansion wells or openings, with the intention of having such cracks as might appear in the walls confined to these places, which, later, would be filled with concrete. A single crack developed at each of four of the wells.

The only crack of importance was one about ¼ in. in average



PLAN AND SECTION
OF HOUSE OVER COAGULATING BASIN
WATER PURIFICATION WORKS,
LITTLE FALLS, N.J.

FIGS. 6 AND 7.

width, which extended through the expansion well of the division wall in the clear-water basin, across the floor of the south basin and part way up the outer wall of the latter at the expansion well. This was repaired before water was turned on, and no leaks of consequence were detected in any of the walls of the coagulating basin or clear-water basin when the plant was placed in service. In fact, appreciable amounts of moisture on the outside of the walls were noticeable in only two or three instances.

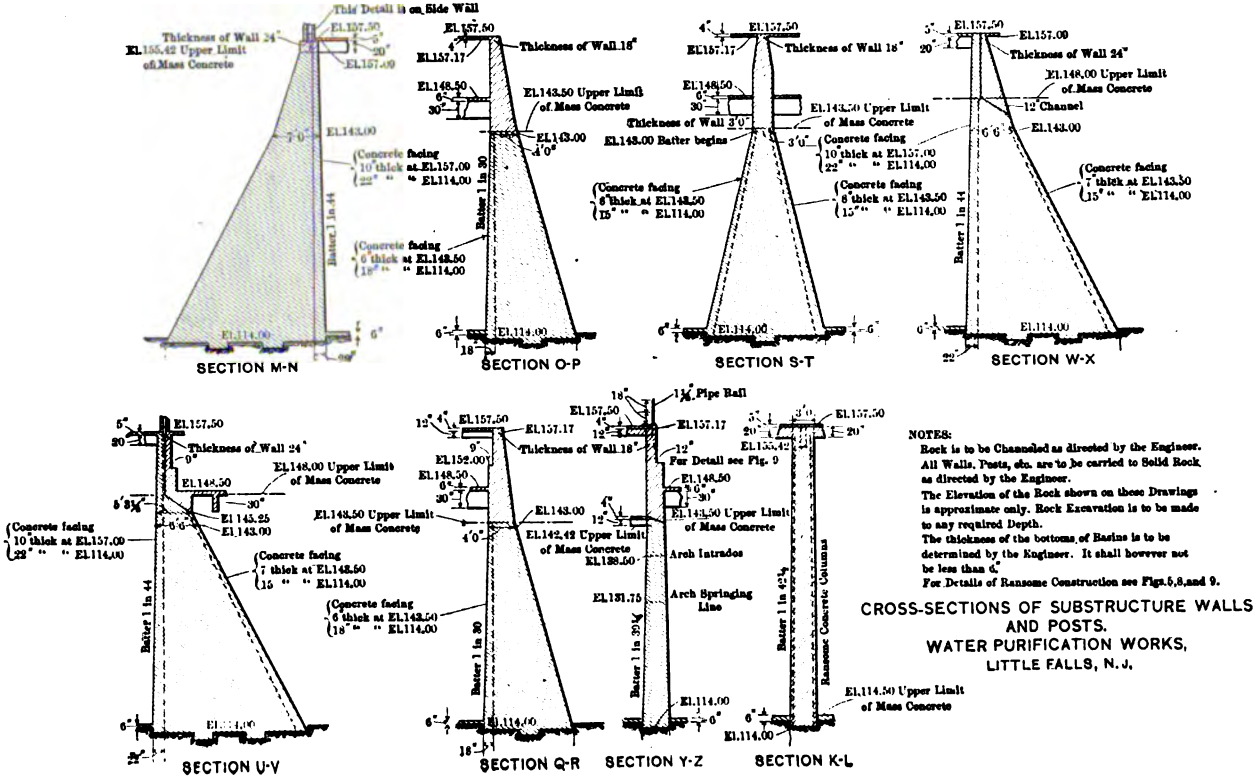
Upon emptying the basins during the past month no cracks were detected in the walls of the coagulating basin, but a very narrow crack was noted opposite the expansion well in the wall separating the coagulating basin from the south compartment of the clear-water basin. It extends some 20 ft. from the bottom, and, under a head of about 40 ft., water was oozing from the lower end at the rate of about ½ gall. per minute.

Each filter tank, 15 x 24 ft. and 8 ft. deep, was built as a continuous box of concrete reinforced with twisted steel roads in each direction, placed as shown in Fig. 9. It was specified that each of these filter tanks when started should be built continuously until completed. The concrete used in these tanks was mixed in the proportions of about 1 : 2 : 4, and was laid very wet. Vulcanite cement was used principally for this portion of the work. All the filter tanks were plastered on the inside with a ½-in. coat of rich mortar, in the proportions of 1 part of cement to 1 part of sand. The inner walls of the tanks below the sand surface were roughened by stippling with a wire brush before the plastered surface had thoroughly set. In no instance have there been any cracks or leaks in these filter tanks.

The concrete roof over the filters, which was built as a part of each respective tank, is 4 ins. thick, supported by Ransome concrete beams 4 x 12 ins., placed 54½ ins. apart.

The floor of the main building, over the coagulating basin, has a thickness of 5 ins., with Ransome concrete beams spaced 4 ft. apart. One end of each beam is supported by the walls of the basin and the other by a central Ransome concrete girder, 8 x 36 ins., with three 1¼-in. rods. This girder is supported by Ransome concrete columns, 4 ft. square at the base and 43 ft. high.

The tanks for preparing solutions of sulphate of alumina, of which there are two, each 17 ft. deep and 16 ft. in diameter, are built of Ran-


This Detail is on Side Wall
Thickness of Wall 24"
El. 155.42 Upper Limit of Mass Concrete
El. 157.50
El. 157.00
7'0"
El. 143.00
Concrete facing 10" thick at El. 157.00, 22" " " El. 114.00
Concrete facing 6" thick at El. 148.50, 18" " " El. 114.00
Batter 1 in 44
El. 114.00
SECTION M-N
El. 157.50
El. 157.17
Thickness of Wall 18"
El. 148.50
El. 143.50 Upper Limit of Mass Concrete
El. 143.00
4'0"
Batter 1 in 30
El. 114.00
SECTION O-P
El. 157.50
El. 157.17
Thickness of Wall 18"
El. 148.50
El. 143.50 Upper Limit of Mass Concrete
Thickness of Wall 3'0"
El. 143.00 Batter begins
3'0"
Concrete facing 10" thick at El. 157.00, 22" " " El. 114.00
Concrete facing 8" thick at El. 143.50, 15" " " El. 114.00
El. 114.00
SECTION S-T
El. 157.50
El. 157.00
Thickness of Wall 24"
El. 148.00 Upper Limit of Mass Concrete
12" Channel
6'6"
El. 143.00
Concrete facing 7" thick at El. 143.50, 15" " " El. 114.00
Batter 1 in 44
El. 114.00
SECTION W-X
El. 157.50
Thickness of Wall 24"
El. 148.00 Upper Limit of Mass Concrete
El. 148.50
El. 145.25
El. 143.00
6'0"
Concrete facing 10" thick at El. 157.00, 22" " " El. 114.00
Concrete facing 7" thick at El. 148.50, 15" " " El. 114.00
Batter 1 in 44
SECTION U-V
El. 157.50
El. 157.17
Thickness of Wall 18"
El. 152.00
El. 148.50
El. 148.50 Upper Limit of Mass Concrete
El. 143.00
4'0"
El. 142.42 Upper Limit of Mass Concrete
Concrete facing 6" thick at El. 143.50, 18" " " El. 114.00
Batter 1 in 30
El. 114.00
SECTION Q-R
1¼" Pipe Rail
El. 157.50
El. 157.17
For Detail see Fig. 9
El. 148.50
El. 143.50 Upper Limit of Mass Concrete
El. 138.50
Arch Intrados
El. 131.75
Arch Springing Line
Batter 1 in 39¼
El. 114.00
SECTION Y-Z
El. 157.50
El. 155.42
Batter 1 in 42¼
Ransome Concrete Columns
El. 114.50 Upper Limit of Mass Concrete
El. 114.00
SECTION K-L

NOTES:

Rock is to be Channeled as directed by the Engineer.

All Walls, Posts, etc. are to be carried to Solid Rock as directed by the Engineer.

The Elevation of the Rock shown on these Drawings is approximate only. Rock Excavation is to be made to any required Depth.

The thickness of the bottoms of Basins is to be determined by the Engineer. It shall however not be less than 6."

For Details of Ransome Construction see Figs. 5, 8, and 9.

CROSS-SECTIONS OF SUBSTRUCTURE WALLS
AND POSTS.
WATER PURIFICATION WORKS,
LITTLE FALLS, N. J.

FIG. 8.

some concrete, and are placed beneath the floor of the main house.

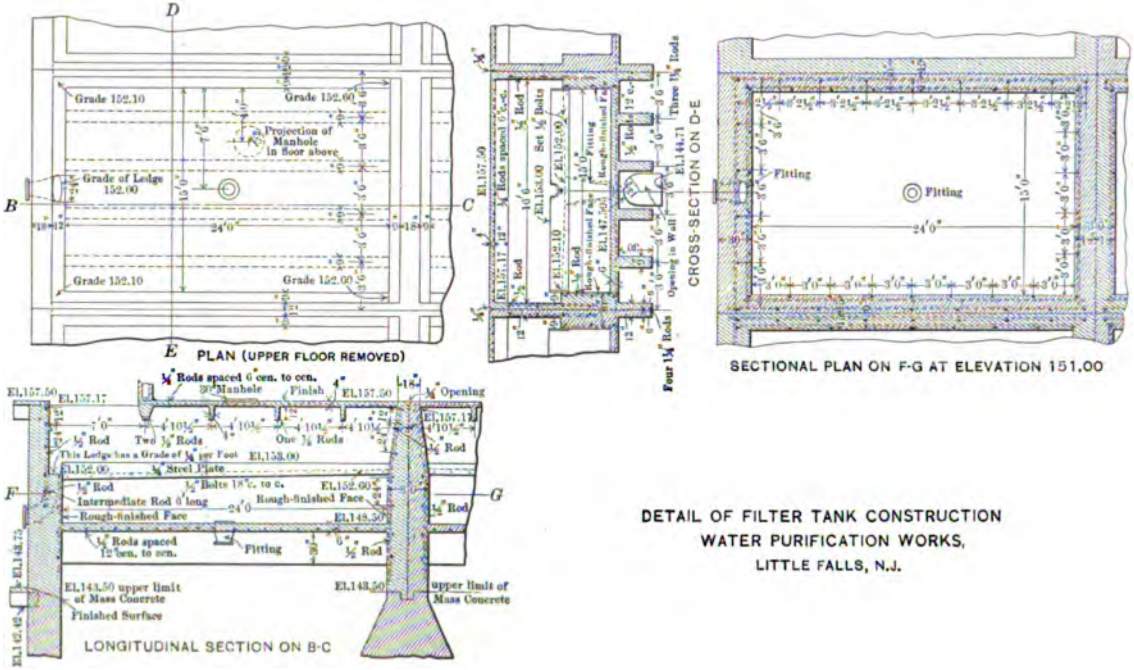
The main house over the coagulating basin, about 46 ft. wide and 132 ft. long, has hollow concrete walls 13 ft. high. The slate and tile roof is supported by steel trusses. The two filter houses, forming wings to the main house, are also built with hollow concrete walls. In order to make the buildings harmonize with the pump-house, the cement was colored to resemble brown stone.

Expansion joints in the walls of the buildings were provided, back of each pilaster, with the view of preventing cracks. Very few cracks have appeared elsewhere.

Regarding the specifications, it may be of interest to state that the Water Company furnished the cement for the substructures, which were built strictly in accordance with the plans, the Water Company taking full responsibility as to stability and water-tightness. The superstructure, including all tanks, was built under a guaranty in these respects. The contractor furnished the cement, and had the option of increasing the quantities of concrete and metal above those shown in the plans, which were the minimum permitted by the Water Company. The guaranteed safe loads per square foot were: 800 lbs. for the floor of the filter tanks, 200 lbs. for the roof of the filters, 350 lbs. for the floor of the pipe gallery, 200 lbs. for the operating platform, and 300 lbs. for the floor of the main building. As to the filter equipment, the Filtration Company guaranteed specified efficiencies for the machinery, and that all devices should perform successfully the work for which they were designed, when judged from a strictly physical or mechanical standpoint. The Water Company took full responsibility as to the behavior of the plant in treating the water.

DESCRIPTION OF THE DETAILS OF THE PRINCIPAL DEVICES.

Application of Coagulant.—Sulphate of alumina is used as the coagulating chemical. It is received in barrels in carload lots, and stored in the main building. The dry chemical is weighed and dumped into the chutes leading to the dissolving tanks situated below the floor in the store-room. In these tanks saturated solutions are prepared, and, to accelerate the dissolving action, heavy bronze stirrers are provided, which revolve slowly in the mass of chemical in the tanks. From these dissolving tanks, each of which has a capacity of 252 galls., the solutions flow through cement pipes to the mixing



PLAN (UPPER FLOOR REMOVED)

CROSS-SECTION ON D-E

SECTIONAL PLAN ON F-G AT ELEVATION 151,00

LONGITUDINAL SECTION ON B-C

DETAIL OF FILTER TANK CONSTRUCTION
WATER PURIFICATION WORKS,
LITTLE FALLS, N.J.

FIG. 9.

tanks. These are of concrete, circular in plan, 17 ft. deep, and each holding about 25 000 galls. The saturated solutions are here diluted to any desired degree by the addition of filtered water. Uniformity in strength of solutions is maintained by frequent stirring by air agitation, the air being supplied from rotary, belt-driven blowers, about 75 cu. ft. of free air per minute being distributed through a radial system of air-pipes at the bottom of each tank.

The solutions are lifted from the mixing tanks, by centrifugal pumps, to the orifice tanks, which are in duplicate, built of concrete, 4 ft. in diameter, of a capacity of 340 galls. each, and situated on a platform in the machinery-room, with the flow line at Elevation 170, or about 13 ft. above the water line of the coagulating basin.

The centrifugal pumps are of standard pattern, cast of special bronze, and are operated by direct-connected electric motors. All pipes, valves and fittings are of hard rubber. All devices are in duplicate, only one set being used at a time.

The quantity of solution pumped from the mixing tanks to the orifice tank may be regulated in the latter, approximately, by a piston valve operated by a float, but it is always kept slightly in excess of the amount being used, and there is an overflow pipe through which the excess is returned to the mixing tank. In this way there is maintained a constant level in the orifice tank, and hence a constant head on the orifice through which the solution passes from the elevated tank to the raw river water.

As the solution leaves the orifice tank it flows into a concrete funnel on the mouth of a 2-in. pipe, which conveys it to the discharge manifold. The latter is located in the mouth of the main inlet pipe, and is a wrought-iron frame holding a grid of ½-in. brass pipes tapped into a 2-in. brass header. The branches are 6 ins. apart, and each one has ¼-in. holes, on 6-in. centers, through which the coagulant solution is discharged. The total number of holes in this discharge manifold is 100. The manifold is hung in vertical slides from the stand-pipe, and can be raised or lowered readily by means of wire ropes and a windlass.

Regulation of Coagulant Feed.—At the bottom of the orifice tank there is a rectangular slot, made of hard rubber and having a fixed width of ¼ in. By means of a slide, which works over the face of this orifice, the length of this opening may be adjusted from 0 to 6 ins.

PUMPING STATION AND FILTRATION PLANT, LITTLE FALLS, N. J.

Adjustment is made by a rod, which connects with the slide in the tank and passes through the side of the tank to a frame. A milled wheel in a fixed bearing, with a fine adjusting thread, is used to move the orifice plate. A pointer on the rod, over a fixed scale, indicates the length of the opening and facilitates adjustment. The orifice is calibrated for the different divisions of the indicator, and a diagram is used to indicate the corresponding flow.

In the original design provision was made for a series of orifice plates, each plate to contain thirty-two orifices, corresponding to the number of filters. In operation it was the intention to plug as many of these orifices as there were filters out of service, and to have different-sized orifices in each of the series of plates, so as to provide a reasonable range in the rate of application of the sulphate of alumina to the water treated. This design was abandoned, partly on account of the interference with each other of the orifices placed fairly near together, and partly on account of changes in the edges of the orifices due to fine granular deposits which would probably accumulate there.

The device which was built is moderately satisfactory, but has given some trouble, chiefly due to inability to secure at all times a volume of flow corresponding to that indicated by the length of opening of the orifice. Some difficulties of a clogging nature were encountered at first, due principally to splinters from the barrels, which passed through the screens first used in the mixing tanks.

In each of the mixing tanks is an automatic recording gauge which makes a constant record of the depth of solution. For periods of several hours, the differences in the level of the solution in the tank, as read from the gauge, give a satisfactory record of the quantity of solution used. Owing to the size of the tanks, however, this does not give an immediate detection of a change in the rate of flow. This information is now obtained by a float in the orifice tank, which rings a gong as soon as the level of the solution in the small tanks drops 1 in. That is, if the flow is interrupted, in degree equivalent to the full flow for less than one minute, the fact is announced by this gong. Changes in the rate of application of the coagulant solution are secured ordinarily by the indicator connected with the calibrated screw for changing the length of the orifice, but at intervals this is checked by means of a small measuring tank holding about 30 galls., and through which the solution passes on its way to the discharging manifold in the mouth of the main inlet pipe. With the devices for controlling the coagulant solution as they now stand, it is considered that this branch of the plant is under satisfactory control.

Application of Soda Ash.—At times of heavy floods the alkalinity of the river water becomes very low, and at rare intervals it is necessary to add some alkali in order to ensure complete decomposition of the applied coagulant. Solutions of soda ash are used for this purpose. They are prepared in iron tanks, 6 ft. in diameter and 6 ft. deep. Both hot and cold water are piped to these tanks, in each of which there is a false bottom of perforated brass on which the dry chemical is placed. The tanks are then filled from below, preferably with hot water, the upward current furnishing sufficient agitation to stir the solution. Ordinarily, the solutions as used contain 5% of soda ash. From the tanks, the soda solution is pumped by a triplex pump operated by an electric motor, and enters the raw water in the main inlet pipe about 175 ft. from its entrance into the coagulating basin. Black-iron pipe is used throughout for the soda outfit. The regulation of the flow of the solution is obtained entirely by the speed of the pump.

Cleaning the Basins.—As the bottom of the coagulating basin and of the clear-water basin is below low water in the river, it is necessary, for purposes of cleaning, to pump out the contents of the lower 6 to 10 ft. In the coagulating basin there is a sump, located as shown on the plans, to which the floor slopes slightly. Cast-iron suction pipes lead from this sump to duplicate vertical centrifugal pumps located in the sludge pump well outside the main structure, as shown in Fig. 3. There is also a suction pipe for these pumps extending to suitable sumps in the clear-water basin. To prevent any admission of water from the coagulating basin to the clear-water basin, the valves from these pipes are designed to be interlocked. The pumps are operated by electric motors set on a platform in the well just above high water. The discharge pipes from the sludge pumps are arranged so as to allow a direct discharge of the sediment into the river, or, if desired, into the catch-basin at the eastern end of the plant, from which the overflow reaches the river after leaving behind the bulk of the sediment.

To facilitate the removal of the last portion of the sediment in the coagulating basin, six hose connections with the high-service filtered-water main are distributed around the basin, about 4 ft. from the

PLATE XIX.
PAPERS, AM. SOC. C. E.
FEBRUARY, 1903.
FULLER ON FILTRATION PLANT.

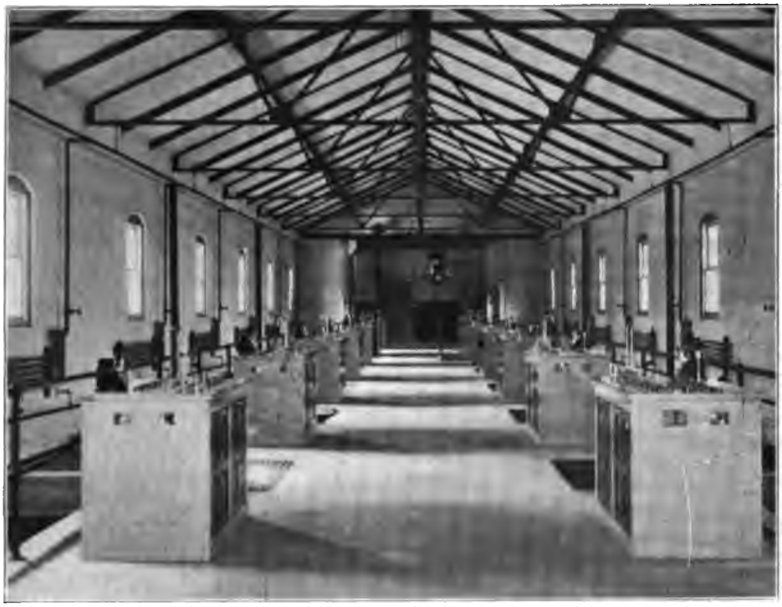


FIG. 1.—OPERATING-ROOM, LITTLE FALLS FILTRATION PLANT.

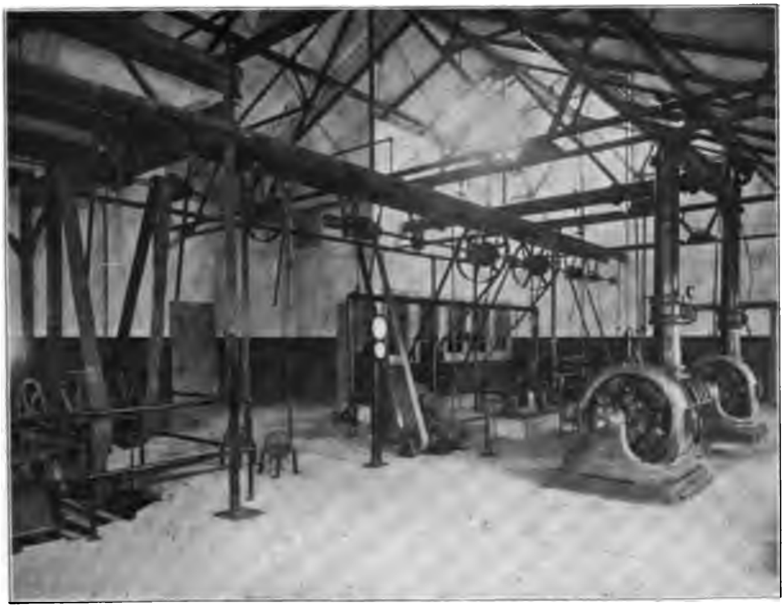


FIG. 2.—MACHINERY-ROOM, LITTLE FALLS FILTRATION PLANT.

bottom. Thus far, the water for flushing purposes has been obtained by opening the gates at the bottom of the stand-pipe, thus admitting raw river water.

Filter-Strainer System.—The strainer system in the floor of the filter comprises a cast-iron header, oval in section, 12 x 6 ins., running lengthwise of the tank in the center, to which are connected 1¾-in. cast-iron laterals, set 6 3/32 ins. from center to center. The laterals are cemented into the header, and extend to the sides of the tank, where their ends are closed with cement plugs. Into the header and the laterals are screwed strainers of the Continental type, on 6¼-in. centers, there being 1 316 strainers in each filter tank.

The body of these strainers is made of hard cast brass, and the top of cupped brass plate. In each strainer there are 33 holes, 1/16 in. in diameter in the top and sides. The neck of the strainer is a ⅜-in. brass tube, which extends into the cast-iron lateral to within ¾ in. of the bottom. This extension tube forms a trap when air is applied, and the air passes from the lateral through a perforation in this extension tube, 3/32 in. in diameter, and located just below the upper wall of the cast-iron lateral.

The connection to the strainer system from below is through the bottom of the tank at the center, where a cast-iron ring is set in the concrete. The central tee of the strainer manifold is bolted to this ring at the top, and at the bottom are fastened the pipe connections which provide an outlet for the filtered water and the inlet for the water and air used in washing. By means of a special double pipe-casting, air is admitted to the strainer system at the top of the central manifold tee, an internal casting in the pipe connection passing up through the ring casting and into the tee. To the lower end of the opening of this internal pipe is connected the air supply line, which passes beneath the floor of the filter to the main air line in the pipe gallery. The outer portion of this special casting forms a water channel, and is connected with the pipe passing under the floor of the filter to the pipe gallery, and is used as an outlet for the filtered water and an inlet for the wash-water.

The space between the lateral pipes is filled with gravel and covered with a cement surface to give a level floor just below the strainers. The construction was such as to facilitate, in case of repairs, ready removal and replacement. The cement surface was coated with two layers of brick preservative paint, to prevent solution of the cement before it had completely set.

The general arrangement of this strainer system is shown in Plate XXI. At the ordinary rate of filtration the linear velocity of the water in the main header of the manifold, as it leaves the filter tank, is about 2 ft. per second. In the laterals, as the water enters the main header, the velocity is about 1 ft. per second. The exit area of the orifices is equal to 0.37 sq. in. per square foot of filtering surface.

The size of the orifices in the strainer system, $\frac{1}{16}$ in., is larger than in the case of most mechanical filter plants now in service, and it is believed that the resulting freedom from clogging, which, in many instances, is characteristic of fine perforations or fine slots, is a distinct advantage. It is necessary, however, with this type of strainer, always to use gravel to support the sand and prevent it from reaching the orifices. The arrangement of this gravel is described under "Filtering Materials."

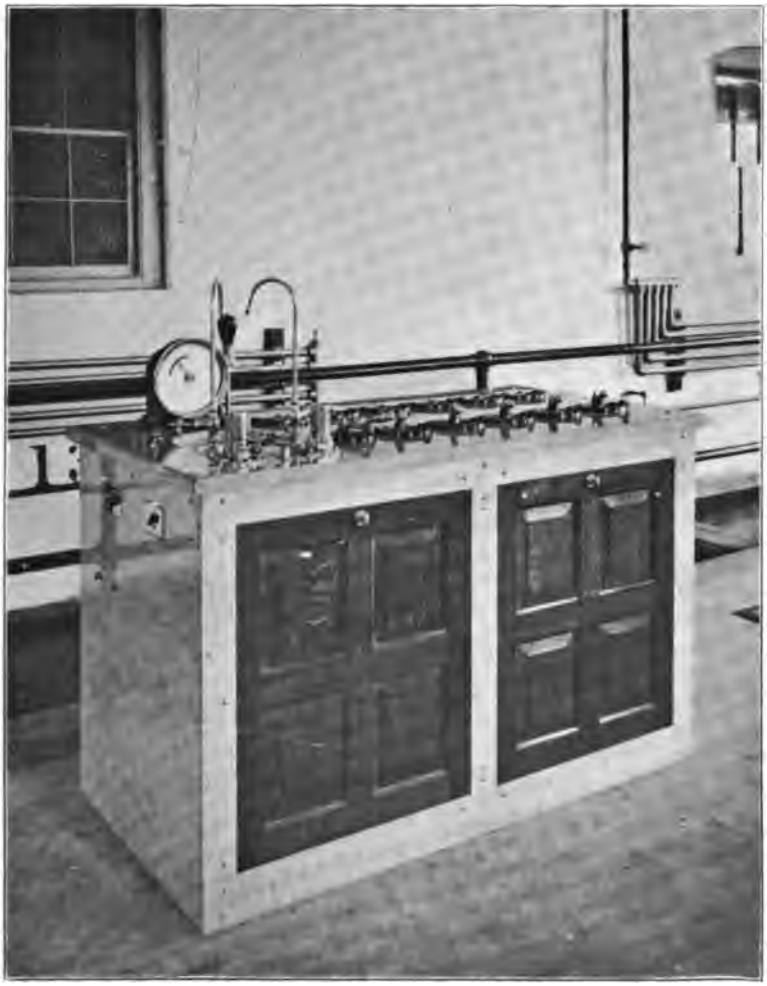
The total loss of head, including both friction and velocity head, through the strainer system and outlet pipe, at the normal rate of filtration, 2 galls. per square foot per minute, is about 0.7 ft.

Filtering Materials.—On the floor of the filter there are 2 ins. of broken quartz, above which is a 5-in. layer of finer quartz. The object of these quartz layers, as indicated previously, is to protect the strainer system from the entrance of sand into the orifices and through the outlet pipe into the controllers. The coarser of these two gravel layers was passed through a screen having 4 meshes to the linear inch, and was retained on a screen having 8 meshes. Its effective size is 4.4 mm., and its uniformity coefficient is 1.30. The finer gravel layer was screened between 8 and 12 meshes to the inch. Its effective size is 2.00 mm., and its uniformity coefficient is 1.45.

The success of these gravel layers depends upon the selection of materials of such hydraulic subsiding value that they are not unseated when wash-water is applied at the velocities used, and of a size fine enough to prevent the sand from passing through them.

Regarding the filtering sand, the filter tanks in the north wing are the only ones which have as yet been filled. As this was the only portion of the plant to go into service during the first year, it was decided that it would be advisable to try different sizes of filtering sand and then charge the tanks in the south wing at a later date with the

PLATE XX.
PAPERS, AM. SOC. C. E.
FEBRUARY, 1903.
FULLER ON FILTRATION PLANT.



An Operating Table, Little Falls Filtration Plant.

material which was found to give most satisfactory service under the actual local conditions.

It was specified that the filtering sand, which is 30 ins. in thickness, should have an effective size within the limits of 0.35 to 0.42 mm., with a uniformity coefficient of not more than 1.50. Not more than 1%, by weight, of the sand was allowed to be finer than 0.25 mm., and not more than 0.2% finer than 0.20 mm.

Considerable difficulty was experienced in getting suitable sand. The two sand dealers with whom the contract was placed by the Filtration Company failed to deliver the material, and the commencement of operations was delayed fully one month, during which time the joint efforts of all concerned were devoted to securing suitable sand from any available source. Part of the sand came from near Oyster Bay, Long Island, part from Roslyn, Long Island, and part from Hanover, N. J. The difficulty consisted principally in getting sand from which the fine material was properly eliminated. It was not found feasible, with the screening outfits as built and operated at the several places, to remove the fine material by screening under water. Screening of the sand when absolutely dry seemed to be the only thoroughly successful method of securing the material specified. Sand screening at the several places was watched by representatives of the Water Company, and Allen Hazen, M. Am. Soc. C. E., in the interests of the Water Company, also advised.

The final outcome was that sand containing a considerable excess of fine material was allowed to go into the tanks, and the fine particles were removed by repeated washing of the material in place and scraping of the surface layers. In many cases as much as one-third of the sand as delivered was removed from the filter tanks by scraping. In this way satisfactory results were obtained finally.

As already stated, it was decided to make some differential tests during regular operations, in order to discover the most suitable size of sand for these filters. It was arranged to have two filter tanks charged with relatively coarse material, two others with relatively fine material, and the other twelve tanks in the north wing charged with material fulfilling the original specifications. A summary of the mechanical analyses of the materials in the sixteen filters now in use is given in Table No. 1.

The analyses summarized in Table No. 1 were made during the second month of service of the filters. In December, about ¼ in., on an average, was scraped from the surface of the filters. Analyses now being made indicate that the effective size, on an average, has increased about 0.02 mm. The analyses given in Table No. 1 are representative of the conditions under which the results of operation recorded in this paper were obtained.

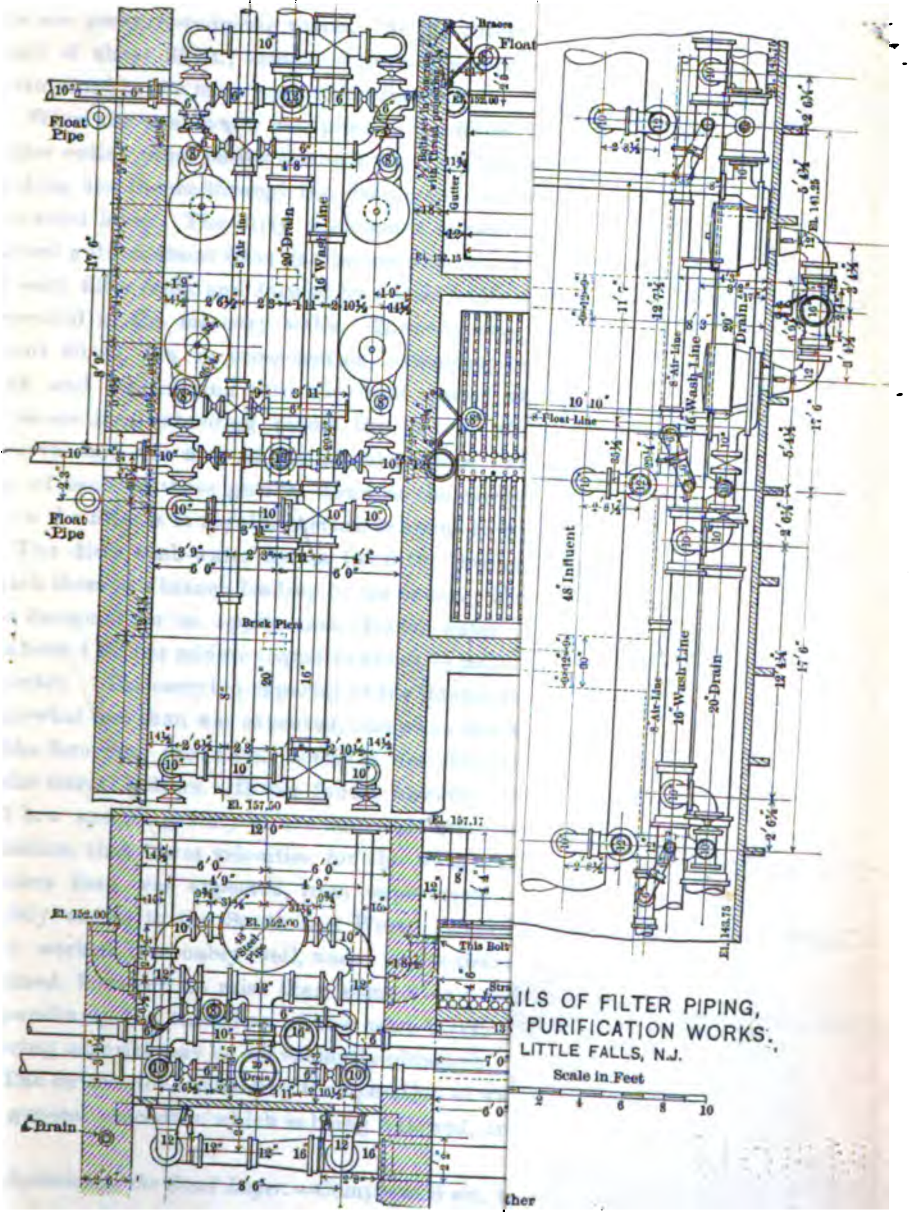
TABLE No. 1.—Summary of the Mechanical Analyses of Filtering Sands.

Number of filter.	Effective size, in millimeters. (10% finer than.)	Uniformity coefficient.	Percentage finer than:	
			0.25 mm.	0.20 mm.
1	0.44	1.32	0	0
2	0.40	1.50	0	0
3	0.37	1.38	0.2	0
4	0.41	1.44	0	0
5	0.38	1.50	0.4	0.1
6	0.41	1.44	0.1	0
7	0.35	1.50	0.5	0.2
8	0.42	1.48	0.4	0.1
9	0.40	1.42	0.5	0
10	0.41	1.46	0.4	0.2
11	0.37	1.41	0.3	0.1
12	0.46	1.50	0.4	0
13	0.39	1.50	0.2	0.1
14	0.39	1.50	0.2	0.1
15	0.39	1.46	0.2	0.1
16	0.38	1.50	0.1	0.2

The loss of head due to friction in 30 ins. of sand of normal size (effective size 0.41 mm., and uniformity coefficient 1.45) when clean is 1.1, 1.7 and 2.6 ft., respectively, for rates of filtration of 80, 125 and 185 millions of gallons per acre daily. For the coarse sand (effective size 0.46 mm., and uniformity coefficient 1.40) the loss is 1.4 ft. for a rate of 125 000 000 galls. per acre daily.

Wash-Water Appliances.—Wash-water is ordinarily applied to the filters by centrifugal pumps operated by direct-connected motors, and which take their supply from the clear-water basin below the filters. One centrifugal pump and motor is placed in the bottom of each pipe gallery. These pumps have a capacity of 3 000 galls. per minute. The piping is cross-connected, so that either pump may be used for washing one filter at a time in either wing. The wash-water lines are also connected with the force mains leading from the pumping station to the distributing reservoirs in the districts supplied with filtered water. On this connection to the high-pressure

PLATE XXI.
PAPERS, AM. SOC. C. E.
FEBRUARY, 1903.
FULLER ON FILTRATION WORKS.



ILS OF FILTER PIPING,
PURIFICATION WORKS.
LITTLE FALLS, N.J.

Scale in Feet

0 2 4 6 8 10

line are pressure-reducing valves. As the filters are now operated, a head of about 25 ft., measured from the floor of the filter tanks, is maintained in the main wash-water line.

When the wash-water is applied to the filters it enters the filtered-water outlet pipe, passes through the manifold pipe of the strainer-system, and thence through the strainers themselves into and through the sand layer. The dirty wash-water is removed, in part, through lateral gutters about 60 sq. ins. in cross-section, placed along the sides of each filter tank, and formed by a steel plate attached to the ledge provided in the masonry walls. There is also a central gutter, of about 85 sq. ins. in cross-section, extending from the rear of the tank and discharging into the front gutter about 140 sq. ins. in cross-section, extending across the end of the filter, and which receives also the flow of the lateral gutters. The distance from the top of each of these gutters down to the surface of the sand layer, when the filter is in regular service, is about 12 ins.

The dirty wash-water leaves the filter through the inlet pipe, to which there is a branch leading to the sewer. The wash-water system was designed for an application of wash-water at a vertical velocity of about 1 ft. per minute (equal to about 7½ galls. per square foot per minute). The carrying capacity of the lateral and central gutters is somewhat less than was expected, and when the wash-water is applied at the foregoing rate a weir action is not obtained for the full length of the lateral gutters. It was found, however, owing to the fineness and low specific gravity of the materials removed from the water by filtration, that lower velocities for the wash-water are more advantageous than was expected, from experiences with filters treating muddy waters in the South and West. Accordingly, these gutters have worked reasonably well, under the existing conditions. It is planned, however, to raise them some 3 or 4 ins. and increase correspondingly the thickness of the sand layer, as soon as additional filtering material may be conveniently obtained.

The devices for facilitating the operation of washing the filters, and the general procedure which is being followed, are considered further on.

Agitation of the Sand Layer.—Compressed air, under a low pressure, is used in agitating the sand layer and facilitating the removal of the accumulated materials during washing, in place of the mechanical stirring devices with rake arms, such as have been used in the majority of filter plants now in service. In the machinery-room there are two No. 3, Root's rotary blowers, of standard make, direct-connected with electric motors. Each has a guaranteed capacity of 1 500 cu. ft. of free air per minute, under a pressure of 5 lbs. From the main air line, running lengthwise of each pipe gallery, there is a branch to each filter, passing beneath the filter floor and entering the special casting below the center of the floor of the filter. The air is delivered at the top of this casting, thence it passes through the manifold piping system to the trapped strainers, next through a small orifice in the strainer-tube extension near the top of each lateral pipe, and thence through the several strainers. The rate of application of air used ordinarily is about 1 000 cu. ft. per minute, under a pressure of 3 lbs. The distribution of the air through all the strainers is uniform to a satisfactory degree, and it agitates the sand bed efficiently, causing the grains to be rubbed together, and with facility freed from the films of organic and other matters which surround the individual grains.

In no instance is agitation with air used at the same time that the wash-water is applied to the filters. The application of air forms the first step in the process of cleaning, and then, after the wash-water has been applied to secure fairly thorough cleaning, the air has been again applied for about one minute to effect further cleansing. During the application of air the water stands in the filters about 4 ins. above the top of the sand surface, or 8 ins. below the top of the overflow gutters. The applied air raises the sand layer about 3 ins., but it does not cause the entire mass to become floated as in the process of washing. Water is always used after the last application of air, and thus the sand layers are freed from any entrained air. The application of air in the manner described does not effect any appreciable grading of the sand grains.

Filter Piping and Connections.—Plate XXI shows a plan and section indicating the size and general arrangement of the piping, all of which is placed within the pipe gallery, together with the connections to the filters. The sizes of the leading pipes are as follows:

Main raw-water supply	48 ins.
" wash-water supply	16 "
" air supply	8 "
" drain	20 "
Individual filtered-water outlet	10 "
" raw-water inlet	12 "
" air line	6 "

The main inlet pipe is of riveted steel, and is carried on hangers attached to the Ransome beams supporting the operating floor. All other pipe is of cast iron. Flange valves were used throughout, but hub and spigot joints were put in wherever possible, both on account of cost and the greater ease of erection and connection to the masonry structures. It was the aim, also, to distribute the flange and hub connections so that in the event of a break the broken piece would be most easily removed.

Effluent Controller.—Each filter is provided with an automatic controller, of the well-known Weston type, consisting essentially of a moving orifice operated by a float in an open compartment. The water enters the controller through butterfly valves, which are operated by the float. The action of these controllers is to maintain a uniform rate of discharge, independent of the head on the outlet pipe. Accordingly, the filters are always operated during filtration with the valve on the outlet pipe wide open, and the flow is controlled automatically by this device.

Orifice discs of three different sizes are provided with each controller, giving yields of about 1 000 000, 1 250 000 and 1 500 000 galls. per filter per 24 hours, respectively. There are also a few special discs to give a daily yield of 650 000 galls.

The head lost in these controllers, as measured from the water level in the outlet stand-pipe (when the float in the controller is seated) to the top of the pipe gallery floor, is about 2.5, 3.0, or 4 0 ft., when the yields of the filters are 650 000, 1 000 000 or 1 500 000 galls. daily, respectively.

These controllers are placed in the bottom of the filter gallery, and discharge the filtered water through an outlet pipe directly into the clear-water basin below. By means of a galvanized-iron funnel and cross-connection pipe, the water from any filter may be discharged into the opposite compartment of the clear-water basin when desired.

Hydraulic Valves.—All the valves on the filter piping are of Rensselaer make, are generally light-weight, double-disc gate-valves, and are operated by hydraulic cylinders. The valves on the wash-water line are all heavy weight. The water to operate these cylinders is furnished by a separate, high-service line, the connections from which are controlled by special four-way cocks. They are operated by levers, with indicators showing the position of the valves, conveniently located on the operating table in front of each filter on the platform above the pipe gallery.

Loss-of-Head Gauges.—On each operating table there is a loss-of-head gauge, the dial of which is operated by a float in the water above the sand layer in the filter, and the pointer of which is operated by a float in a small stand-pipe connected to the outlet pipe through which the filtered water passes to the controller. These gauges, which were designed and made by the Filtration Company, are somewhat novel, in that there is an automatic adjustment of the zero point of the gauge to different water levels in the filters. By means of this adjustable dial the reading of the pointer gives the frictional resistance, or loss of head, in the filter at any time. Electrical connection is made when the loss of head reaches the maximum, so that a bell is rung and an electric light is turned on, thus warning the operator that it is time to wash the filter.

Available Head.—The gross head available, measured from the top of the filter tanks to the maximum water level in the clear-water basin, is 14 ft. Ordinarily, the water level on the filters is kept about 1 ft. below the top of the filter walls, giving an available head of 13 ft.

In a filter containing normal sand, and operated at the regular rate (1 000 000 galls. per 24 hours), the loss of head, directly after washing, averages 2.3 ft. Adding this to the head lost by the controller, there is left a net effective head of 7.7 ft. for overcoming the friction caused by the accumulations of sediment, etc., in the sand layer. With a filter containing coarse sand (0.46 mm. effective size), and operated at the regular rate, this effective head is 8.0 ft. With a filter containing normal sand, and operated at a rate of 1 500 000 galls. per 24 hours, the net effective head is 5 ft.

Arrangement of Devices for Operating the Plant.—Unusual attention was given to making the operation of this plant as automatic as practicable, with provisions for indicating to the man in charge the status of the various operations at all times.

Mention has already been made of the devices in connection with the preparation and regulation of the flow of the chemical solutions, the automatic filter controllers, hydraulic cylinders for the operation of the valves, and the loss-of-head gauges. In addition to these the detailed arrangements include gauges for indicating the water levels in the coagulating basin and clear-water basin, and devices for sampling the water as it passes through the plant. In the general office are two glass cylinders through which pass constant streams of raw and filtered water.

Each filter is provided with an arrangement by which a sample of filtered water from it may be collected readily at any time. In the pipe gallery opposite the outlet pipe of each filter is a small Pelton water-wheel operated from the high-service line. This wheel operates two ½-in. centrifugal pumps, the suction of one of which is in the filter outlet pipe, and the other in the filter inlet pipe. The discharge of each is piped to the operating table, where there are cocks on the pipes to control the flow into a sink. These devices enable the operator to collect at each filter samples of the raw water on its way to the filter, the filtered water as it leaves the filter, or the dirty wash-water after it leaves the filter during the washing process. There are, also, at each operating table, sight tubes, the intended purpose of which is to show the character of the filtered water, the raw water, or the dirty wash-water, as the case may be. These devices for inspecting the filtered water and collecting samples of it have proved very helpful. The sight-tubes, however, as they now stand, have not proved very satisfactory, owing to the illumination being furnished by lamps which are not suitable. The intense brown appearance of the dirty wash-water, due to the organic matter contained therein, makes it improbable that the sight-tubes will ever be of much assistance in this plant in determining when the application of wash-water should cease. This can be found much better by an inspection of the water in the filter tank itself, which is illuminated by an electric light favorably situated.

Plates XIX and XX show the general arrangement of the filter-house and the marble operating tables placed opposite each filter.

DESCRIPTION AND RESULTS OF OPERATION.

In brief terms, the general procedure of operating a mechanical filter plant of this character may be said to consist of the preparation of solutions of coagulating chemical, the application of the same to the river water in quantities adapted to its character, the cleaning of the filters from time to time when the clogging materials in the sand layers exhaust the available head, and the adjustment of the number of filters in service to yield the quantity of filtered water corresponding to the demands made upon the clear-water basin by the main pumping station.

With a plant equipped with such automatic devices as are provided at these works the operation of the filters themselves is a simple matter, and can be entrusted to ordinary intelligent laborers, subject to the oversight of a foreman. The preparation and application of solutions of coagulant require somewhat more attention, and, to be done effectively, and at the same time economically, there is required the attention of an intelligent and watchful superintendent capable of taking advantage of a certain amount of analytical evidence showing from time to time the character of the water which he has to treat. There are, of course, some other matters occasionally requiring attention, such as the cleaning of the coagulating basin, the packing of valves, and other work incidental to such a system of piping and mechanical appliances.

These filtration works, as already stated, have been in continuous service since September 4th, 1902. During the first year of service this plant is being operated under the general oversight of the writer, and during the first six months it has been under the immediate charge of Mr. George A. Johnson.

The object of conducting a series of careful investigations of the plant during its initial year of service is to obtain information whereby the plant can be operated to best advantage in the treatment of the local water as it passes through its various seasonal changes, and especially to ascertain the most judicious manner of coagulating the water and of washing the filters, and to prepare schedules whereby the regular attendants may operate the plant properly, at a later date.

As already stated, the filter tanks in the south wing have not yet been charged with sand, and among the special studies undertaken is that of the determination of the size of sand best adapted to local conditions. These and other matters led to establishing at the outset a schedule which involved the determination of data upon several points of importance.

Differential Tests.—Twelve of the sixteen filters in the north wing have been used regularly for obtaining data for differential or comparative purposes. They consist of six pairs, in duplicate. One pair contains the normal sand as originally specified, another coarse sand, another fine sand, another normal sand operated at a high rate, and another normal sand operated at a low rate. The final pair contains normal sand in which no air is used in cleaning the sand layers. Wash-water and air are applied in the same manner to the five pairs of filters first mentioned. Unless otherwise stated, the rate of filtration is normal, 125 000 000 galls. per acre daily, or about 2 galls. per square foot per minute. The remaining filters in the north wing, when in service, are used for studying the best rate of application of wash-water and of air, and of other allied matters which can be taken up as individual studies.

The essential details of the twelve filters used for differential purposes are indicated in Table No. 2.

TABLE No. 2.—SUMMARY OF THE ESSENTIAL DETAILS OF FILTERS.

Filter number.	SAND LAYER.			Air used in washing.	RATE OF FILTRATION.	
	Grade.	Effective size. Millimeters.	Uniformity coefficient.		Millions of gallons per acre daily.	Approximate gallons per square foot per minute.
1	Coarse.	0.44	1.33	Yes.	125	2
12	Coarse.	0.46	1.50	Yes.	125	2
3	Fine.	0.37	1.38	Yes.	125	2
7	Fine.	0.35	1.51	Yes.	125	2
2	Normal.	0.40	1.50	Yes.	125	2
8	Normal.	0.42	1.43	Yes.	125	2
13	Normal.	0.39	1.50	No.	125	2
16	Normal.	0.38	1.50	No.	125	2
9	Normal.	0.40	1.42	Yes.	80	1.25
10	Normal.	0.41	1.46	Yes.	80	1.25
4	Normal.	0.41	1.44	Yes.	185	3
6	Normal.	0.41	1.44	Yes.	185	3

Force Employed.—Owing to the amount of work involved by the special tests, together with all other special studies indicated herein, the force employed in the operation of these works, up to the present time, has been considerably in excess of that which will suffice later. It is also to be borne in mind that at the outset the attendants employed for the operation of this plant were entirely unfamiliar with the operation of mechanical filters, and that there has been necessary a period of instruction during which it was important not to require of the men more detailed observations than they could readily make. Thus far, Mr. Johnson has been assisted by nine men, three of whom were technically trained. Of the latter, one devoted himself exclusively to engineering matters and the compilation of results, one to analytical work, and the third to general work both in the laboratory and in operating the plant. There is one filter attendant on each watch of twelve hours, and one man in the machinery-room. There is also one mechanic on duty during the day, and one boy, as general helper in the laboratory and as janitor.

When the plant is operating at full capacity in the future, it is expected that there will be two trained men, say, a superintendent and an assistant superintendent, both of whom will be familiar with ordinary analytical matters, and two filter attendants and one attendant in the machinery-room, on each watch. Besides these there will be a janitor or laboratory helper. At times there will be required some service by a mechanic, in connection with the machinery, but it is expected that this can be attended to by the mechanics employed at the pumping station nearby. Assuming that there will be required the service of a mechanic equal to continuous labor of one man per day, the total force employed, with 12-hour shifts, would be ten men, including the man in charge and his principal assistant.

Observations and Analyses Made.—A close watch has been kept upon all principal features connected with the operation of these works. Hourly readings of the levels of the water in the coagulating basin and clear-water basin, and in the coagulant solution tanks are taken and recorded, as well as of the loss of head as indicated by the gauges on each filter in service. Careful records are also made of all observations connected with the washing of filters, enabling a continuous and complete record to be maintained for each filter, as to the periods between washings, the quantity of water filtered and the amount of wash-water and air applied.

Regarding analytical work, samples of the river water and the effluents of the coagulating basin and the clear-water basin are collected three times a day, to be examined for numbers of bacteria, amount of turbidity, color, amorphous matter and alkalinity. The water before and after filtration is also examined for color and turbidity at 2-hour intervals. At least once each day, a sample from the effluent of each individual filter in service is examined bacterially. From time to time samples of the filtered water from each filter in turn have been collected at frequent intervals, to show the uniformity in composition of the filtered water. At frequent intervals most careful tests have also been made regarding the presence of coagulant in the filtered water. Once a week, as a rule, chemical analyses of the raw and filtered water have been made. In addition to this, many special observations have been made, in order to throw light upon such matters as the best manner of washing the filters, judged by the rate at which the clogged materials were removed from the sand layer, as shown by the character of the dirty wash-water. Frequent analyses of the sand layers have also been made, not only for their contents as to bacteria and suspended matters, but also to show their uniformity in size as indicated by mechanical analyses.

Up to February 1st, the amount of analytical work performed is indicated by Table No. 3.

TABLE No. 3.—SUMMARY OF ANALYTICAL WORK.

Complete chemical analyses	30
Partial analyses, for alkalinity, alumina, color and turbidity	5 120
Other special analyses, including specific gravity of coagulant solution	340
Complete microscopical examinations	16
Partial examinations for amorphous matter	148
Examination for numbers of bacteria	4 260
Mechanical analyses of filtering material	545

Record of Results.—A record of the principal results obtained is given in Tables Nos. 4 and 5.

Table No. 4 is a summary of the leading results by days, including the amount of coagulant applied, the percentage of wash-water, and the alkalinity, turbidity, color, amorphous matter and bacteria in the river water, the effluent of the coagulating basin and the effluent of the filters.

Table No. 5 shows the results of the chemical analyses of the raw and filtered water.

The number of microscopical organisms in the river water has ranged from 20 to 200 per cubic centimeter.

Coagulant.—Sulphate of alumina is the coagulant which has been used regularly thus far. Arrangements have been made for the application of copperas and lime, with the view to seeing if such treatment is applicable for purposes of coagulation under the existing local conditions, and, if so, to ascertain the cost, as compared with sulphate of alumina.

TABLE No. 4—(*Continued*).

DAILY SUMMARY OF LEADING AVERAGE RESULTS OF OPERATION.

Day, Oct., 1902.*	Period between washings. Hours.	Percentage of wash-water.	Sulphate of alumina. Grains per gallon.	PARTS PER MILLION.								PER CUBIC CENTIMETER.				
				Alkalinity.		Turbidity.			Color.			Amorphous matter.		Bacteria.		
				River water.	Filt. water.	River water.	Subs. water.	Filt. water.	River water.	Subs. water.	Filt. water.	River water.	Subs. water.	River water.	Subs. water.	Filt. water.
1..............	9.87	4.1	1.76	18	9	12	8	0	50	30	7	3 500	620	11 000	850	60
2..............	8.86	4.2	1.67	16	7	10	7	0	48	31	6	2 000	600	2 800	170	28
3..............	8.31	4.1	1.22	19	9	9	7	0	48	19	12	1 100	600	2 100	250	73
4.......... ...	6.65	5.4	1.19	19	12	9	5	2	50	33	27	1 050	400	1 000	290	275
5..............	6.10	5.9	1.49	19	11	8	6	2	50	32	19	1 200	300	2 700	325	65
6..............	6.97	4.9	1.55	20	8	8	7	0	50	29	8	1 500	300	2 700	325	28
7..............	7.02	4.8	1.40	19	10	8	6	0	51	27	7	800	200	1 200	650	80
8..............	6.57	5.8	1.36	21	10	8	6	0	52	28	8	800	290	750	700	24
9.......... ...	5.84	5.9	1.36	20	11	7	5	1	51	27	9	1 500	600	2 800	425	160
10..............	6.17	5.4	1.44	22	12	6	5	1	58	35	12	1 500	500	2 300	1 100	200
11..............	6.68	5.5	2.01	22	18	5	4	1	59	36	9	500	200	6 800	950	220
12..............	5.76	6.0	1.65	18	11	4	3	0	51	30	4	....	....	14 000	1 800	300
13..............	8.03	4.8	1.46	17	9	5	4	1	56	37	5	800	100	8 700	1 000	160
14..............	6.64	5.9	1.31	23	12	5	4	1	55	37	10	1 000	300	6 900	450	170
15..............	7.51	4.5	1.79	24	10	5	5	1	57	27	6	1 200	500	600	160	19
16..............	8.18	4.8	1.93	23	10	5	4	1	57	28	8	1 500	500	325	200	11
17..............	8.85	3.8	2.17	23	7	4	3	1	54	33	8	1 000	400	500	180	12
18..............	8.23	4.1	1.95	27	7	3	3	1	51	29	3	800	200	600	100	16
19..............	8.81	4.8	1.65	26	11	3	3	2	53	30	2	700	400	800	120	15
20..............	6.20	6.0	1.68	26	14	3	3	2	52	33	5	1 000	200	275	120	25
21..............	8.50	4.5	1.61	29	12	3	3	2	53	34	6	1 500	400	300	140	50
22..............	7.02	5.5	1.65	26	18	4	5	1	53	36	6	1 209	400	700	350	48
23..............	7.19	5.1	1.66	27	14	5	3	1	53	32	6	1 000	400	1 000	450	36
24..............	7.40	5.4	1.65	30	16	3	4	1	54	33	4	1 200	400	1 000	600	60
25..............	9.85	3.6	1.73	32	18	4	4	1	53	35	3	1 000	300	3 100	475	80
26..............	8.83	3.8	1.52	36	20	4	4	2	49	29	3	1 200	350	1 600	900	150
27..............	8.61	3.8	1.45	32	20	3	3	2	49	26	2	800	290	3 900	1 000	100
28..............	8.86	4.4	1.54	28	15	7	5	2	42	33	2	800	300	13 900	3 200	110
29..............	11.39	3.3	1.45	18	8	7	6	1	51	34	4	900	300	13 600	1 100	100
30..............	10.27	3.8	1.61	18	9	5	5	1	51	29	4	700	280	7 200	1 500	95
31..............	8.12	4.5	1.52	17	7	7	7	1	50	22	4	600	180	3 500	1 400	34
Averages......	7.79	4.8	1.59	23	12	6	5	1	52	31	7	1 100	330	3 800	650	90

TABLE No. 4.

DAILY SUMMARY OF LEADING AVERAGE RESULTS OF OPERATION.

Day, Sept., 1903.	Period between washings. Hours.	Percentage of wash-water.	Sulphate of alumina. Grains per gallon.	Parts per Million.								Per Cubic Centimeter.				
				Alkalinity.		Turbidity.			Color.			Amorphous matter.		Bacteria.		
				River water.	Filt. water.	River water.	Subs. water.	Filt. water.	River. water.	Subs. water.	Filt. water.	River water.	Subs. water.	River water.	Subs. water.	Filt. water.
4	6.61	5.3	1.31	51	41	7	..	3	28	..	6	......	......	1 100	......	200
5	10.12	3.8	0.64	50	44	8	..	2	30	..	8	......	......	1 500	......	150
6	10.55	3.5	0.39	51	44	8	..	3	32	..	10	......	......	2 000	......	150
7	11.49	2.9	0.32	48	46	8	5	5	29	15	15	......	......	2 000	1 300	200
8	14.52	2.4	0.35	48	46	9	4	5	29	21	15	......	......	400	......	210
9	10.13	3.3	0.29	56	46	9	4	5	29	20	16	......	......	4 000	1 100	400
10	8.23	4.2	0.75	54	48	11	5	2	28	10	7	......	......	1 000	500	350
11	7.65	4.4	0.68	46	40	10	5	2	28	10	8	......	......	1 400	425	170
12	8.47	4 0	0.52	44	39	9	5	2	25	10	8	......	......	1 600	500	170
13	8.90	3.9	0.62	39	34	8	4	2	25	18	15	......	......	1 900	400	170
14	8.68	4.2	0.64	39	35	8	4	2	24	..	10	......	......	......	......	....
15	8.00	4.3	0.67	40	35	9	4	2	28	15	10	......	......	1 300	500	160
16	7.98	4.2	0.65	41	36	9	5	2	28	16	7	......	......	850	475	110
17	8.01	3.9	0.72	45	40	7	3	2	28	15	8	......	......	700	350	170
18	8.12	4.1	0.74	44	39	9	5	2	26	18	8	......	......	1 500	1 000	150
19	9.00	3.7	0.78	43	38	9	5	2	28	28	4	......	......	2 500	400	210
20	8.10	4.0	0.70	44	38	8	4	2	31	20	7	......	......	1 700	250	150
21	7.67	4.3	0.83	45	39	8	6	2	36	22	9	......	......	1 500	375	120
22	8.52	3.9	0.80	47	40	11	..	2	45	24	6	......	......	1 000	750	325
23	7.03	4.9	0.79	47	41	7	4	2	22	18	6	......	......	400	250	80
24	7.71	4.5	0.83	47	42	7	4	2	26	19	6	......	......	400	110	30
25	7.23	4.9	0.61	49	43	8	3	2	25	18	7	.....	......	700	65	60
26	6.82	5.2	0.74	48	39	11	7	3	24	28	11	......	......	......	......	....
27	6.35	6.3	0.75	28	23	20	14	5	33	25	25	......	......	......	......	....
28	7.42	5.0	1.19	17	12	15	10	4	35	32	24	......	......	3 600	2 000	300
29	7.89	4.6	1.24	16	9	18	11	3	54	33	21	2 800	......	12 000	8 000	400
30	7.22	5.1	1.31	19	9	15	8	3	53	34	22	2 400	......	30 000	59 000	230
Averages	8.46	4.3	0.74	42	36	10	6	3	31	20	11	......	......	5 400	3 900	190

The quantity of amorphous matter is expressed in standard units, according to Whipple's method. Standard nutrient gelatine, reaction 1½% acid, is used in determining the numbers of bacteria, the period of cultivation being 48 hours, at 20° Cent.

TABLE No. 4—(*Continued*).

DAILY SUMMARY OF LEADING AVERAGE RESULTS OF OPERATION.

Day, Dec., 1902.	Period between washings. Hours.	Percentage of wash-water.	Sulphate of alumina. Grains per gallon.	PARTS PER MILLION.								PER CUBIC CENTIMETER.				
				Alkalinity.		Turbidity.			Color.			Amorphous matter.		Bacteria.		
				River water.	Filt. water.	River water.	Subs. water.	Filt. water.	River water.	Subs. water.	Filt. water.	River water.	Subs. water.	River water.	Subs. water.	Filt. water.
1	13.18	3.2	1.70	32	19	4	3	1	47	33	5	120	50	5 500	2 300	75
2	11.60	3.5	1.59	32	18	3	3	1	43	32	6	130	70	4 800	1 900	40
3	14.91	2.9	1.72	30	17	5	3	2	46	29	4	110	40	3 900	2 400	50
4	10.84	3.8	1.61	28	16	4	1	1	46	29	5	110	40	9 200	3 000	40
5	12.11	3.5	1.82	26	18	5	3	1	48	31	6	130	50	13 000	3 300	35
6	11.52	3.7	1.48	23	13	5	3	1	53	37	6	250	70	10 100	2 500	75
7	10.22	4.2	1.75	25	12	4	3	0	45	30	6	350	90	9 800	1 700	55
8	10.89	3.8	1.73	25	13	4	2	1	48	28	6	300	150	9 200	3 200	140
9	9.38	4.5	1.53	25	18	3	2	1	47	27	4	280	100	7 200	3 300	375
10	10.94	3.8	1.73	27	18	3	2	0	51	21	6	240	110	5 300	2 100	100
11	8.64	4.5	1.70	28	14	3	1	1	47	20	6	160	80	3 400	1 100	33
12	12.36	3.2	1.75	28	16	3	2	0	37	18	5	150	70	2 800	1 100	30
13	8.73	4.5	2.01	28	17	2	1	1	41	29	6	130	70	2 800	600	29
14	9.80	4.1	1.68	29	17	2	1	1	35	18	6	190	100	2 100	500	25
15	11.09	3.6	1.72	28	17	2	1	1	34	18	5	250	130	3 700	400	25
16	7.75	5.2	1.83	23	14	6	4	1	42	18	5	230	130	6 600	1 100	32
17	5.91	7.4	1.85	10	7	10	5	1	49	19	4	1 700	500	10 100	500	60
18	9.09	4.5	2.00	10	6	14	8	2	44	24	5	800	400	9 200	2 200	60
19	8.29	4.7	1.79	10	7	18	8	2	51	25	6	600	300	8 900	4 800	70
20	8.77	4.4	1.76	11	7	16	11	1	42	21	4	800	160	9 900	2 500	45
21	9.27	4.5	1.98	12	7	11	7	0	41	23	4	1 000	500	4 400	1 700	18
22	8.16	4.9	1.82	9	6	19	15	1	48	25	4	1 200	450	5 800	1 700	27
23	8.23	4.9	1.84	8	5	19	8	1	43	21	3	1 100	550	3 200	1 600	25
24	10.38	4.1	1.72	10	6	12	6	1	38	21	5	900	500	6 800	2 300	39
25	10.24	3.9	1.73	11	8	7	5	0	49	22	4	800	390	4 000	1 400	35
26	10.51	3.8	1.77	12	8	9	7	1	45	20	5	600	320	4 200	1 200	36
27	9.98	3.9	1.87	14	12	7	4	0	45	20	4	500	280	3 600	1 700	28
28	9.55	4.0	1.49	15	10	9	4	0	41	23	4	410	250	3 600	1 000	14
29	9.13	4.1	1.46	17	9	9	4	1	43	25	4	310	180	6 700	850	11
30	9.56	4.0	1.49	18	8	4	3	0	32	22	4	250	180	2 300	800	7
31	9.43	4.1	1.35	18	9	3	2	1	28	18	5	200	100	1 700	800	6
Averages	10.02	4.2	1.70	23	12	7	4	1	44	24	5	450	210	5 300	1 300	50

TABLE No. 4—(*Continued.*)

Daily Summary of Leading Average Results of Operation.

Day, Nov., 1902.	Period between washings. Hours.	Percentage of wash-water.	Sulphate of alumina. Grains per gallon.	Parts per Million.								Per Cubic Centimeter.				
				Alkalinity.		Turbidity.			Color.			Amorphous matter.		Bacteria.		
				River water.	Filt. water.	River water.	Subs. water.	Filt. water.	River water.	Subs. water.	Filt. water.	River water.	Subs. water.	River water.	Subs. water.	Filt. water.
1	7.41	5.0	1.05	19	14	4	4	3	51	.45	28	800	290	1 700	1 300	210
2	3.98	10.8	1.63	20	13	6	6	3	47	34	14	700	220	1 300	500	70
3	7.93	5.4	1.55	21	11	3	3	2	49	24	4	400	140	1 200	225	19
4	7.63	5.3	1.57	22	11	4	3	2	50	33	5	300	90	1 800	350	24
5	6.99	6.0	1.70	24	11	5	4	2	51	39	6	210	60	1 200	400	48
6	7.47	5.4	1.76	25	13	5	4	1	52	28	6	400	95	1 800	550	12
7	7.44	5.7	1.81	26	16	6	4	1	49	28	6	500	100	2 400	550	11
8	8.13	4.8	1.44	26	18	6	4	2	47	16	7	280	80	3 100	550	33
9	7.81	5.5	1.94	27	15	5	3	2	44	25	5	340	90	2 800	550	60
10	4.54	10.9	1.75	27	15	5	3	1	47	38	5	120	85	1 900	375	45
11	9.12	4.8	1.80	29	22	5	3	2	47	33	20	310	75	3 100	425	15
12	11.97	3.4	1.79	29	18	5	3	1	49	33	4	190	50	1 400	475	16
13	10.12	4.0	1.71	29	18	5	3	3	45	24	5	150	40	1 800	500	22
14	12.29	3.3	1.60	32	21	5	4	2	46	30	5	110	40	2 600	800	27
15	10.09	3.8	1.65	33	20	5	3	2	49	31	4	400	95	1.700	1 000	25
16	10.75	4.0	1.64	32	21	6	5	3	45	29	4	300	85	2 900	650	25
17	11.81	3.7	1.47	32	22	7	5	2	41	28	4	350	100	1 900	600	23
18	10.84	3.7	1.56	35	22	6	4	2	39	26	5	200	55	1 500	900	22
19	10.68	4.8	1.77	35	22	5	5	3	38	27	4	170	40	1 800	450	11
20	10.64	3.8	1.64	36	24	5	5	3	39	28	8	150	40	1 400	475	19
21	10.88	3.8	1.75	36	24	5	5	2	42	23	4	230	50	2 800	500	7
22	11.70	3.5	1.78	35	24	6	5	1	41	24	8	200	50	4 200	850	37
23	11.50	3.5	1.58	36	25	3	3	2	43	26	4	150	60	7 000	1 800	42
24	11.14	3.8	1.60	35	24	4	4	1	44	27	8	180	40	5 000	2 100	170
25	10.14	3.9	1.35	35	25	3	3	1	44	27	5	250	50	8 000	5 000	90
26	8.56	4.8	1.41	35	26	3	3	.1	38	30	5	280	70	5 200	2 200	325
27	8.09	5.4	1.31	34	23	3	3	1	43	24	6	300	80	6 700	2 900	180
28	11.46	3.7	1.57	34	22	4	4	2	49	24	5	180	40	9 800	3 600	100
29	10.29	4.1	1.89	33	19	5	5	1	47	36	6	120	50	11 600	2 800	100
30	12.79	3.4	1.73	32	17	5	5	2	45	32	7	100	80	5 400	1 500	20
Averages	9.46	4.8	1.63	30	19	5	4	2	45	28	7	280	80	3 500	1 100	60

TABLE No. 4—(*Concluded*).

Daily Summary of Leading Average Results of Operation.

Day, Jan., 1908.	Period between washings. Hours.	Percentage of wash-water.	Sulphate of alumina. Grains per gallon.	Parts per Million.								Per Cubic Centimeter.				
				Alkalinity.		Turbidity.			Color.			Amorphous matter.		Bacteria.		
				River water.	Filt. water.	River water.	Subs. water.	Filt. water.	River water.	Subs. water.	Filt. water.	River water.	Subs. water.	River water.	Subs. water.	Filt. water.
1	10.82	3.6	1.05	20	11	2	2	0	39	20	4	220	100	1 700	750	12
2	13.09	3.1	0.93	21	13	3	2	0	28	18	3	180	75	1 500	1 200	21
3	10.08	4.0	1.12	19	12	4	3	0	25	18	4	100	50	3 300	1 600	12
4	10.83	3.8	1.08	16	9	3	2	0	25	17	6	90	40	4 400	2 600	17
5	12.81	3.1	0.90	16	9	4	3	1	28	18	5	100	50	4 400	2 600	80
6	11.62	3.3	0.68	16	10	5	3	0	37	21	5	80	40	3 700	1 300	140
7	13.41	2.9	0.57	17	11	4	3	0	35	24	10	140	110	2 400	2 000	400
8	10.54	3.6	0.68	17	12	3	2	0	32	26	5	130	70	1 600	1 200	275
9	13.11	3.0	0.64	18	13	3	1	1	32	19	6	120	80	1 200	850	65
10	11.79	3.2	0.67	19	14	2	1	0	29	22	6	140	90	2 200	210	55
11	12.40	3.0	0.66	20	16	1	2	0	29	19	6	160	70	650	190	110
12	13.52	2.9	0.66	21	16	5	3	1	25	20	4	190	110	2 100	900	150
13	9.71	4.2	6.76	24	18	4	3	1	27	23	6	150	190	1 600	500	160
14	12.79	3.0	0.61	24	20	4	2	0	28	18	6	120	70	1 400	1 200	190
15	12.81	2.9	0.69	24	19	4	3	0	28	20	6	110	75	1 500	1 300	70
16	12.75	3.0	0.80	24	18	3	2	0	26	19	5	130	80	1 800	650	80
17	15.90	2.8	0.73	25	20	4	2	0	23	17	5	150	90	2 300	1 400	100
18	13.08	2.2	0.68	25	20	3	3	0	22	16	5	150	75	4 200	1 000	130
19	16.55	2.2	0.65	27	22	3	3	0	22	17	4	140	80	4 000	2 600	190
20	15.88	2.4	0.56	28	24	3	2	0	28	17	5	120	60	5 200	1 200	300
21	12.79	3.0	0.71	23	19	20	17	0	31	24	6	120	70	6 000	2 300	225
22	10.54	3.7	1.08	16	9	23	11	0	35	25	6	700	400	5 600	1 700	120
23	12.64	3.0	0.92	15	8	14	9	0	36	25	5	500	300	4 300	950	80
24	11.80	2.9	0.94	16	9	12	8	0	36	23	5	400	250	3 900	3 000	150
25	14.93	2.3	0.98	17	10	13	12	0	49	33	5	300	160	11 200	3 200	140
26	11.26	3.3	1.06	18	10	12	10	0	46	27	5	210	100	9 400	3 200	85
27	14.02	2.5	1.27	20	11	11	7	0	42	26	5	180	90	6 700	2 900	40
28	12.58	2.9	1.35	21	11	10	6	0	43	26	5	300	130	4 700	1 600	45
29	11.02	3.0	1.24	19	10	9	5	0	35	20	5	280	150	5 800	1 100	22
30	10.80	3.1	1.08	18	11	8	5	0	30	17	4	250	130	4 500	1 300	34
31	12.87	2.8	0.80	16	10	9	7	0	30	20	5	280	150	5 200	3 900	65
Averages	12.67	3.0	0.84	20	14	6	5	0	31	21	5	200	115	4 000	1 700	110

TABLE No. 5.—Results of Chemical Analyses of River Water and Filtered Water.

(Parts per Million.)

Collected.		Source. R = River water. F = Filtered water.	Temperature, in degrees Centigrade.	Silica turbidity.	Color, Plat. standard.	Oxygen consumed.	Nitrogen as: Albuminoid ammonia.						Chlorine.	Sulphuric acid.	Incrusting constituents.	Alkalinity.	Total hardness.	Residue on Evaporation.			Iron.	Carbonic acid (free and half-bound).
Date, 1902.	Hour						Total.	Suspended.	Dissolved.	Free ammonia.	Nitrites.	Nitrates.						Total.	Suspended.	Dissolved.		
Oct. 16	12 M.	R	12	4	58	7.6	0.212	0.069	0.143	0.033	0.004	0.012	2.0	8	4	22	26	77	7	70	0.5	....
Oct. 16	12 M.	F	12	1	3	1.2	0.074	......	......	0.024	0.000	0.080	2.0	11	16	10	26	70	....	....	0.0	....
Oct. 22	12 M.	R	12	4	55	7.6	0.191	0.014	0.177	0.036	0.003	0.018	3.0	8	3	24	27	71	2	69	0.4	10
Oct. 22	12 M.	F	12	0	5	2.1	0.110	......	......	0.027	0.000	0.087	3.0	14	14	11	25	69	....	....	0.2	8
Oct. 29	9 A. M.	R	13	5	51	8.7	0.216	0.031	0.185	0.025	0.003	0.020	4.0	3	3	18	21	69	10	59	0.3	8
Oct. 29	9 A. M.	F	14	1	6	2.0	0.148	......	......	0.021	0.001	0.093	4.0	9	10	10	20	65	....	....	0.1	13
Nov. 5	9 A. M.	R	10	5	50	7.2	0.205	0.006	0.199	0.025	0.003	0.060	4.0	1	1	25	26	73	7	66	0.4	9
Nov. 5	9 A. M.	F	10	1	3	1.7	0.160	......	......	0.009	0.000	0.110	3.8	10	8	12	20	69	....	....	0.0	11
Nov. 26	10 A. M.	R	8	3	48	....	......	......	......	......	0.002	0.105	3.2	....	0	31	31	73	2	71	0.3	12
Nov. 26	10 A. M.	F	9	2	5	....	......	......	......	......	0.004	0.105	3.2	....	4	27	31	75	....	....	0.1	15
Dec. 4	11 A. M.	R	6	4	45	....	......	......	......	......	0.003	0.080	3.5	....	20	28	48	70	2	68	0.2	14
Dec. 4	11 A. M.	F	7	1	7	....	......	......	......	......	0.003	0.085	3.5	....	21	17	38	65	....	....	0.0	14
Dec. 10	2 P. M.	R	5	3	51	....	......	......	......	......	0.003	0.170	3.5	....	18	26	44	79	2	77	0.2	3
Dec. 10	2 P. M.	F	5	1	6	....	......	......	......	......	0.003	0.220	3.5	....	31	13	44	75	....	....	0.0	10
Dec. 17	10 A. M.	R	3	75	70	7.1	0.135	0.060	0.075	0.033	0.004	0.095	2.5	3	7	10	17	88	23	65	0.3	10
Dec. 17	10 A. M.	F	3	1	4	1.3	0.039	......	......	0.018	0.001	0.160	2.5	22	....	9	....	56	....	....	0.0	16
Dec. 24	12 M.	R	3	9	40	5.1	0.019	0.003	0.016	0.008	0.000	0.080	2.0	3	7	25	32	58	7	51	0.2	6
Dec. 24	12 M.	F	3	0	2	1.1	0.015	......	......	0.008	0.000	0.085	1.7	13	9	16	25	49	....	....	0.0	11
Dec. 31	11 A. M.	R	2	4	30	4.7	0.014	0.001	0.013	0.007	0.000	0.160	1.7	3	14	19	33	66	6	60	0.1	6
Dec. 31	11 A. M.	F	2	0	5	1.0	0.011	......	......	0.006	0.000	0.160	1.7	17	26	9	35	60	....	....	0.0	11
1903.																						
Jan. 8	10 A. M.	R	5	5	30	3.8	0.012	0.001	0.011	0.002	0.002	0.210	3.0	4	8	17	25	59	7	52	0.2	10
Jan. 8	10 A. M.	F	4	0	2	1.8	0.008	......	......	0.002	0.003	0.210	2.8	7	12	12	24	73	....	....	0.0	12
Jan. 14	1 P. M.	R	4	4	26	5.1	0.014	0.002	0.012	0.001	0.001	0.150	3.0	3	7	24	31	64	5	59	0.2	12
Jan. 14	1 P. M.	F	4	0	9	2.0	0.010	......	......	0.001	0.001	0.150	3.0	7	10	20	36	70	....	....	0.0	14
Jan. 21	12 M.	R	3	20	28	4.2	0.016	0.002	0.014	0.002	0.003	0.060	4.0	2	3	28	31	70	10	60	0.2	7
Jan. 21	12 M.	F	4	0	6	2.0	0.011	......	......	0.006	0.003	0.060	4.2	6	7	24	31	61	....	....	0.0	6
Jan. 28	11 A. M.	R	4	10	40	4.6	0.014	0.002	0.012	0.004	0.004	0.250	3.0	4	5	21	26	59	7	52	0.3	9
Jan. 28	11 A. M.	F	4	0	5	1.8	0.007	......	......	0.005	0.004	0.250	3.0	12	13	11	24	51	....	...	0.0	12

On December 17th and 24th, the river-water sample was collected at a place before the application of soda reached the water.

The river water has a vegetable or musty odor, usually very slight; but, occasionally, during the autumn, it was quite pronounced. After filtration the odor in the water is somewhat less than in the river water.

The river water and filtered water contain, approximately, the same quantity of dissolved oxygen. In October the quantity was about 80% of that required for saturation. Since cold weather set in, the water has been nearly saturated with atmospheric oxygen, at times completely so.

Solutions of sulphate of alumina have usually been prepared of 2% strength. When the full plant is in operation stronger solutions will be used. The diluter solutions are now used for purposes of securing a better control in the rate of application with the devices in hand.

The sulphate of alumina is obtained from the Pennsylvania Salt Manufacturing Company, and costs about 1 cent per pound. It contains no free sulphuric acid, practically no sediment, and about 17% of water-soluble aluminum oxide, with traces of iron.

Up to February 1st, the quantity of sulphate of alumina applied to the river water averaged 1.30 grains per gallon. Computed from the filtered water, the quantity was 1.35 grains per gallon. The range in quantity applied was from 0.29 to 2.01 grains, depending principally upon the amount of color and amorphous matter contained in the raw river water. Some evidence of the relation between the required amount of coagulant and the removal of color, bacteria, etc., under different conditions is indicated further on.

Soda.—The alkalinity of the river water became low, as compared with that necessary for the decomposition of the sulphate of alumina required for the treatment of the freshet water, during the latter half of December, and from December 17th to 30th, inclusive, there was applied a solution of soda ash, ranging in quantity from 0.16 to 0.63, and averaging 0.49 grain per gallon. During this period there were numerous occasions when the composition of the river water changed quite rapidly, and for this reason it was considered wise to apply soda in somewhat larger quantities and for a somewhat longer period than would appear to be called for by an inspection of the data in Table No. 4. On these occasions it was imperative that analyses of the river water be made from time to time throughout the entire 24 hours. It was the endeavor to apply soda so that the final filtered water would at all times contain at least 5 parts per million of alkalinity, capable of decomposing more than ½ grain of sulphate of alumina per gallon.

Efficiency of Coagulating Basin.—In Table No. 6 is given a monthly summary of the principal constituents of the river water before and after it passed through the coagulating basin. The average period of coagulation is also noted.

Cleaning the Coagulating Basin.—The coagulating basin was first cleaned on November 10th, when there were about 8 ft. of accumulated sediment or sludge on the bottom. This was removed by draining and pumping out the sludge in the lower portion of the basin, river water being applied from time to time by opening the gates at the bottom of the stand-pipe at the north end. The sludge was liquid in its character, so that it formed apparently a layer of uniform thickness over the entire bottom, excepting perhaps over a limited area near the inlet.

TABLE No. 6.—SUMMARY OF RESULTS SHOWING THE EFFICIENCY OF THE COAGULATING BASIN.

Month.	Period of coagulation and subsidence.	TURBIDITY.		COLOR.		AMORPHOUS MATTER.		BACTERIA.	
		River water.	Coag. basin eff.	River water.	Coag. basin eff.	River water.	Coag. basin eff.	River water.	Coag. basin eff.
1902.	Hours.								
September.....	3.1	10	6	31	20	....	....	5 400	3 900
October........	3.3	6	5	52	31	1 100	380	3 800	650
November.....	3.2	5	4	45	28	280	80	3 500	1 100
December......	2.9	7	4	44	24	450	210	5 800	1 800
1903.									
January.......	2.8	6	5	31	21	200	115	4 000	1 700

On January 13th the coagulating basin was again cleaned out, and it was found that there was a layer of sediment about 5 ft. in thickness. The character of this sludge was examined more carefully than on the former occasion, and, from numerous samples, it was found to contain about 87% of water and 13% of dry solids. Of the latter, about 27% was found to be aluminum hydrate; the remainder consisted of the various matters removed from the river water.

There was some decomposition going on in the organic matter of the sludge, as removed, on both occasions, particularly in November, as indicated by the odors in the basin during cleaning. There was no sign, however, of such decomposition as might be classed as a septic action, and the sediment in no place had turned black, as has been noted in some instances, elsewhere.

Method of Washing the Filters.—Numerous studies have been made as to the best rate and pressure for the application of the wash-water, and also the application of air for purposes of agitation, as well as the period during washing when air can be most advantageously applied. According to the evidence now available, the best procedure is to apply air at the commencement of the washing operation, under a pressure of 3 lbs., at a rate of about 20 to 25 galls. of free air per square foot of filtering surface per minute, and for a period of 3 minutes. At the commencement of the application of the air the water in the filter is drawn down to about 4 ins. above the sand layer, or 8 ins. below the overflow gutters. This is necessary, to prevent loss of sand. Next, there is applied filtered water under a pressure of about 25 ft., measured at the strainer system, at a rate of about 5¼ galls. per square foot per minute, equal to about three-fourths of a vertical foot per minute, and continued until the wash-water, as it leaves the filters, is comparatively clean, and sufficiently so to enable the moving particles of sand at the surface of the layer to be readily seen. At this plant the wash-water clears in quite a well-defined manner, and, with a little practice, the attendants have no difficulty in determining when the end point is reached. As a rule, air has been applied a second time for about 1 minute during each washing, followed by the application of wash-water, to remove the air and to clean the sand to the same point as above described. During washing, the sand layer is raised about 3 ins., or to within 9 ins. of the top of the overflow gutter. The quantity of sand lost is very trifling. The average total time required for washing a filter is 12 minutes.

Percentage of Wash-Water Used.—The quantity of wash-water used is estimated from the duration of its application, and numerous observations have been made as to the rate of delivery of the wash-water pump, with the rheostat on the motor set at different points and for different levels of water in the clear-water basin, from which the wash-water pump takes its suction. Further, these measurements are checked repeatedly by noting the rate at which the water rises in the filter tanks and also in a measuring tank at the end of the sewer line into which the discharged wash-water is allowed to flow.

Up to February 1st, the average quantity of wash-water used for the entire plant was 4.2% of the water treated.

Comparisons of the quantity of wash-water required for the so-called normal filters, those of coarse and fine sand, and those operated at high and low rates, are contained in Table No. 7.

TABLE No. 7.—COMPARISON OF THE QUANTITY OF WASH-WATER REQUIRED IN THE CASE OF FILTERS OPERATED UNDER DIFFERENT CONDITIONS.

(Averages for 20 weeks.)

Kind of sand.	Rate of filtration.	Percentage of wash-water required.
Normal	High	3.8
	Normal	4.1
	Low	4.4
Coarse	Normal	3.8
Fine	Normal	4.4

Period of Service.—The period of service of the filters, between washings, depends, of course, upon the character of the water as it reaches the sand layers, and, in general, may be said to bear an inverse relation to the percentage of wash-water. Up to February 1st, the total average period of service between washings of the filters was 9.68 hours. The ordinary range in length of runs of the filters has been from about 6 to 18 hours.

TABLE No. 8.—SUMMARY OF RESULTS SHOWING THE EFFECT OF AIR AGITATION DURING THE PROCESS OF WASHING.

Month.	NORMAL FILTERS.		FILTERS WITHOUT AIR AGITATION.	
	Average period of service. Hours.	Percentage of wash-water.	Average period of service. Hours.	Percentage of wash-water.
September	8.16	3.3	9.19	4.2
October	7.92	4.5	6.12	5.7
November	10.51	4.1	7.35	5.3
December	10.76	4.1	9.11	4.0
January	14.31	2.9	12.29	2.7

Effect of Air Agitation.—Filters Nos. 13 and 16, without exception, have been washed without the application of air. It is yet too soon to discuss comprehensively the value of the air, but an inspection of the sand layers of these two filters after washing shows that they contain sufficiently more clogging material than the regular filters to indicate that the air is of benefit. In November these filters gave shorter runs, and required more wash-water, than the so-called normal filters. An inspection of all sand layers, at that time, with much detail, indicated that there was some fine sand accumulated in the upper quarter of an inch of the majority of the filters. This fine sand was scraped from the surface of each layer. Following that, these two filters, which received no air, became more normal in their operation, as regards the period of service and percentage of wash-water. The data thus far obtained upon this question are given in Table No. 8, showing the average length of service and percentage of wash-water for Nos. 2 and 8, normal filters, and for these special filters, Nos. 13 and 16.

Power Required.—The electric horse-power required for the operation of each of the various devices is indicated in Table No. 9.

TABLE No. 9.

ELECTRIC HORSE-POWER REQUIRED TO OPERATE THE VARIOUS DEVICES.

Motors to Operate.	Rated Horse-Power.
Wash-water pump	75
Blower	45
Chemical feed pump	2
Sludge pump	40
Soda pump	1
Main shafting	10
Effluent gate-valve	5

Removal of Bacteria.—The thoroughness with which the bacteria in the raw water are removed by these filtration works depends essentially upon the quantity of a coagulant applied.

Table No. 4 shows the evidence in the form of daily averages from the commencement of operations to date. By months, the bacterial results, together with the principal information related thereto, are shown in Table No. 10.

During each of the first three months there were quite a number of occasions when the bacteria in the filtered water were somewhat numerous; due, practically without exception, to interruptions in the proper rate of application of the coagulant. As has been stated already, this was due largely to obstruction in the suction of the pumps supplying the orifice tank, in most instances caused by splinters from the barrels containing the sulphate of alumina, and by foreign matters, such as leaves and shavings, getting into the mixing tanks. During this period, when the men were being trained in the operation of the plant, there were several times when these interruptions were not detected until the coagulating basin had received a considerable quantity of river water insufficiently charged with coagulant. At the present time these matters have very little significance, owing to the familiarity with their work, on the part of the attendants, the use of more efficient screens to keep splinters and other matters from the suction of the pumps and the orifice tank, to the gong which is now rung by a float in the orifice tank whenever the solution becomes interrupted for a time equivalent to less than 1 minute's regular flow, and to the measuring cylinder upon the chemical feed pipe, enabling more accurate control to be made of the rate of application. During the month of December, it was the uniform intention to secure a high degree of bacterial efficiency from the filters, and this was done, with the exception that the samples obtained from the 8th to the 10th of December were affected by an interruption in the chemical feed.

TABLE No. 10.—BACTERIAL RESULTS AND PRINCIPAL INFORMATION RELATING THERETO.

(Averages by Months).

Month.	Sulphate of alumina. Grains per gallon.	TURBIDITY.			COLOR.			AMORPHOUS MATTER.		BACTERIA.			
								Standard units per cubic centimeter.		Per cubic centimeter.			Percentage removal.
		River water.	Coag. basin effluent.	Filtered water.	River water.	Coag. basin effluent.	Filtered water.	River water.	Coag. basin effluent.	River water.	Coag. basin effluent.	Filt. water.	
1902.													
Sept.....	0.74	10	6	8	31	20	11	....	....	5 400	3 900	190	96.5
Oct......	1.59	6	5	1	52	31	7	1 100	380	3 800	650	90	97.6
Nov......	1.63	5	4	2	45	28	7	280	80	3 500	1 100	60	98.3
Dec......	1.70	7	4	1	44	24	5	450	210	5 800	1 800	50	99.1
1903.													
Jan......	0.84	6	5	0	31	21	5	200	115	4 000	1 700	110	97.2

During the month of January, lower quantities of coagulant were used intentionally, with the view to seeing the efficiency of different ratios, and, with the uniform rate of application of coagulant, the bacterial results obtained during that month are of most value for this particular purpose.

Removal of Color.—It has been found, as a result of repeated examinations, especially in noting the appearance of the filtered water in a large porcelain-lined bath-tub, that it is not possible for a consumer to recognize any color when the filtered water contains 10 parts per million or less. A color of 20 parts is also practically unnoticeable to the consumer. These works have been operated with the view of keeping the color below 10 parts. It has been found, however, that the quantity of coagulant necessary to reduce it to that point is practically as great as that required to reduce it to 5 parts.

Table No. 11 shows the monthly average results of the applied coagulant, and the color in the raw and filtered water:

TABLE No. 11.—QUANTITIES OF COAGULANT APPLIED.
(Averages by Months.)

Month.	Sulphate of alumina. Grains per gallon.	COLOR.	
		River water.	Filtered water.
1902.			
September	0.74	31	11
October	1.59	52	7
November	1.68	45	7
December	1.70	44	5
1903.			
January	0.84	31	5

Special effort is being made to secure data from which may be deduced certain factors indicating the quantity of coagulant required for the proper treatment of the river water in its various conditions. It is yet too soon to discuss these factors.

Removal of Turbidity.—As noted by the record in Table No. 4, the turbidity of the filtered water usually ranges from nothing to 2 parts. Now and then it becomes as high as 3 parts. All these amounts may be properly recorded as traces, and it may be said that for all practical purposes the filtered water has no turbidity.

Removal of Organic Matter.—Based on the average results given in Table No. 5, the removal of organic matter by these filters is shown in Table No. 12.

TABLE No. 12.—Summary Showing the Removal of Organic Matter.

Parts per Million.				Percentage of Organic Matter Removed.	
Nitrogen as albuminoid ammonia.		Oxygen consumed.			
River water.	Filtered water.	River water.	Filtered water.	Albuminoid ammonia.	Oxygen consumed.
0.121	0.075	6.8	1.6	38	75

Removal of Tastes and Odors.—The Passaic River water ordinarily has a slightly musty or vegetable odor, and at times during the autumn it has a swampy odor which is noticeable to persons unfamiliar with the water, but which is not disagreeable, and, in fact, is hardly recognized by those familiar with surface waters from swampy areas. The removal of tastes and odors by filtration is appreciable, but when the swampy odor is present in the river water it is still clearly recognizable in the filtered water on careful examination. Studies of the practicability of removing it by aeration have been made, but it is found that this is unsuccessful, as the odors and tastes still persist after vigorous aeration for some 10 to 12 hours. The tastes and odors are evidently produced by oily substances liberated from the vegetable growths in the swampy areas, and, apparently, could be removed only by filtration through charcoal, by ozonization, or by intermittent filtration through sand at exceedingly low rates.

Removal of Coagulant.—In no case has the filtered water contained any undecomposed sulphate of alumina. Regarding the removal of the aluminum hydrate, ordinarily this is complete, although now and then the numerous analyses made indicate that faint traces of the hydrate in a very fine colloidal form have appeared in the filtered water. These traces are too small to be measured, although, in a general way, it may be said that there are times when it would probably amount to about 0.06 part per million, equal to 0.0035 grain per gallon. The average would be less than 0.01 part per million, corresponding to a removal of more than 99% of the hydrate contained in the raw water. These traces are gradually diminishing as the sand layers are becoming "ripened."

Change in Hardness.—Table No. 13 gives a comparison of the average hardness of the river and the filtered waters.

TABLE No. 13.—COMPARATIVE HARDNESS OF THE RIVER AND FILTERED WATERS.

Parts per Million.

RIVER WATER.			FILTERED WATER.		
Temporary. (Alkalinity.)	Permanent. (Incrusting constituents.)	Total hardness.	Temporary.	Permanent.	Total hardness.
23	12	35	15	19	34

Effective Size of Sand Grains.—The principal point in relation to the effective size of the sand grains is the importance of removing the fine particles contained in the sand. The specifications, as originally prepared, are none too severe. The effective size, within the range stated (see Table No. 1), and under the local conditions, makes no appreciable difference with regard to the quality of the filtered water, but the coarser sands allow a reduction in the percentage of wash-water used, as shown in Table No. 14.

TABLE No. 14.—PERCENTAGE OF WASH-WATER REQUIRED IN FILTERS CONTAINING DIFFERENT KINDS OF SAND LAYERS.

(Average for 20 weeks.)

Kind of sand.	Percentage of wash-water required.
Fine	4.4
Normal	4.1
Coarse	3.3

Effect of Rate of Filtration.—The rate of filtration, as far as the quality of the filtered water is concerned, does not seem to be a factor of significance. If the applied water is well coagulated, satisfactory results will follow with a rate of filtration at least as high as 185 000 000 galls. per acre per 24 hours, and with an inadequately coagulated water good results cannot be obtained at rates of 80 000 000 galls. per acre per 24 hours, or much less. That the number of bacteria in the filtered water is not materially affected by the rate of filtration is shown by Table No. 15.

TABLE No. 15.—AVERAGE RESULTS, SHOWING REMOVAL OF BACTERIA BY FILTERS OPERATED AT DIFFERENT RATES.

(Averages for 20 weeks.)

Rate of filtration.	RATE OF FILTRATION.		BACTERIA PER CUBIC CENTIMETER.		Percentage of removal of bacteria.
	Gallons per acre daily.	Gallons per square foot per minute.	River water.	Filtered water.	
High................	185 000 000	3.0	3 500	100	97.1
Normal.............	125 000 000	2.0	3 500	90	97.4
Low..................	80 000 000	1.2	3 500	80	97.7

The more recent results, obtained after the sand layers became ripened, show no appreciable differences.

Compared with the normal rate of 125 000 000 galls. the high and low rates affect the period of service and percentage of wash-water as shown in Table No. 16.

TABLE No. 16.—AVERAGE RESULTS SHOWING THE EFFECT OF THE RATE OF FILTRATION ON PERIOD OF SERVICE AND PERCENTAGE OF WASH-WATER.

(Average for 20 weeks.)

Rate of filtration.	Period of service. Hours.	Volume of water filtered per run.	Percentage of wash-water.
High..........................	7.52	470 000	3.8
Normal	10.18	425 000	4.1
Low	12.93	358 000	4.4

The larger yield of filtered water between washings by the high-rate filters, apparently, is explained by the deeper penetration into the sand layers of matters removed from the water. Regarding the percentage of wash-water, the actual volume of water required per filter for cleaning does not seem to be exactly proportional to the amount of accumulated matters in the sand layer.

Regarding Costs.—It is not feasible, at the present time, to discuss questions of cost in as much detail as might be desired. However, information upon the principal items in the operation of the works is contained in the foregoing pages, and the cost of construction per million gallons of nominal daily filtering capacity may be summarized as follows:

Coagulating basin and clear-water basin, including piping within the walls and grading the grounds	$5 400
Supply and suction piping outside the structures	800
Filter tanks, including covers	1 500
Main building and wings, including floors, piers and entire superstructure, except the last item	2 000
Filter equipment, complete, including machinery within the buildings	4 800
Power equipment and outside wiring	800
	$15 300

Acknowledgment.—In closing, the writer desires to record his acknowledgments to J. Waldo Smith, M. Am. Soc. C. E., under whose direction these works were designed and built and are operated, for permission to make use of the data embodied in this paper.

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PAPERS AND DISCUSSIONS.

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AUTOMATIC MODULES FOR REGULATING THE SPEED OF FILTRATION.

By Charles Anthony, Jr., M. Am. Soc. C. E.

To be Presented April 1st, 1903.

Now that the importance of keeping the velocity of sand filtration constant, and below a given maximum, while providing the means of gradually increasing that velocity after each cleansing of the sand surface, has come to be universally recognized, it has occurred to the writer that a short paper treating on the various forms of module, or controller, that have been designed with this object might be of interest.

Numerous forms of semi-automatic apparatus of this description have been devised, but as, under the law of the survival of the fittest, they appear to be doomed to speedy extinction, at all events for the purpose in view, it has not been considered expedient to include any special mention of them herein.

Before proceeding further, it may be well to point out the requirements which an apparatus of this nature should fulfil. They are two-fold:

1st.—It should be susceptible of adjustment to any constant discharge between the limits zero and the maximum volume required.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

2d.—It should be mechanically simple, and of a durable nature, not requiring skilled attention.

All modules that have been designed by, or have come to the notice of, the writer, of which a list is appended in Table No. 1, belong to one or other of the following four categories:

1st.—A weir or orifice, whether surface or submerged, maintained under a constant head by its own movement.

2d.—A fixed, submerged weir, or orifice, kept under constant relative head.

3d.—A governed motor, passing a constant volume at a constant velocity.

4th.—A submerged orifice, closed automatically in such ratio to the head as to give a uniform discharge.

TABLE No. 1.

	Description of Module.	Means of Varying the Discharge.
	1st Category.	
1.	Surface weir supported by float at constant depth	Submergence variable.
2.	Surface weir, as above	Width of weir variable.
3.	Submerged weir, as above	Submergence variable.
4.	Submerged weir, as above	Size of orifice variable.
5.	Floating siphon	Head variable.
6.	Floating siphon	Size of orifice variable.
	2d Category.	
7.	Balanced valve, keeping pressure constant on orifice	Pressure variable.
8.	Balanced valve, keeping pressure constant on orifice	Size of orifice variable.
9.	Head on submerged weir kept constant by relative motion of floats on up- and down-stream sides	Head variable.
10.	Head on submerged weir kept constant by relative motion of floats on up- and down-stream sides	Size of orifice variable.

AUTOMATIC MODULES
FOR REGULATING THE SPEED OF FILTRATION.

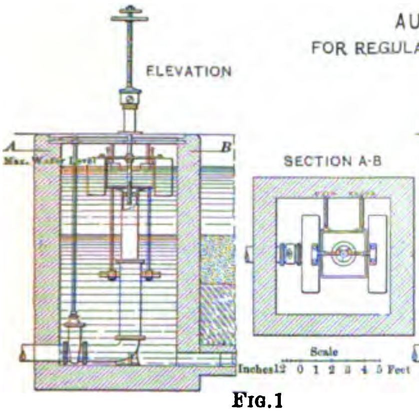

FIG. 1

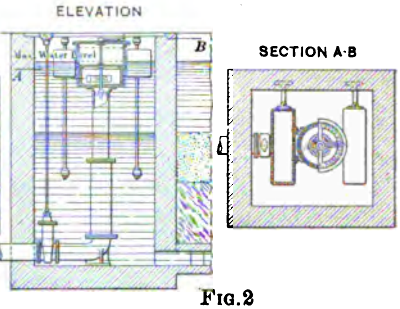

FIG. 2

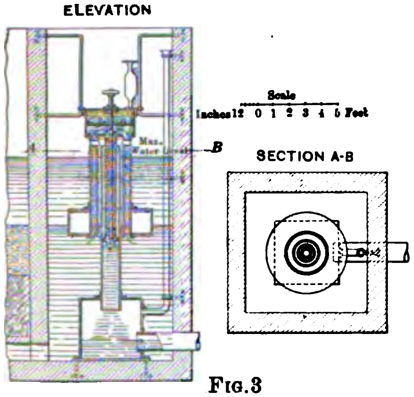

FIG. 3

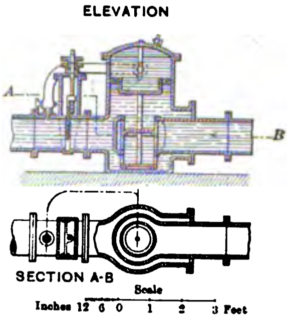

FIG. 4

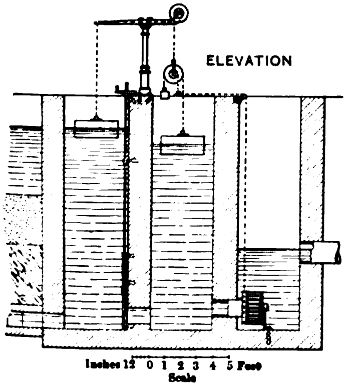

FIG. 5

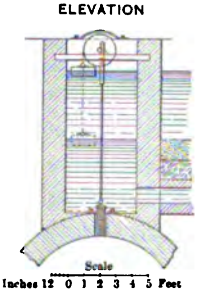

FIG. 6

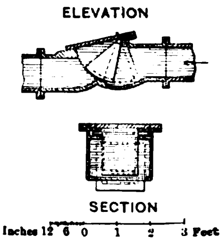

FIG. 7

3D CATEGORY.

11. Turbine or motor, driven by passing water, and governed. Speed variable.
12. Turbine or motor, driven by passing water, and governed. Capacity of motor variable.

4TH CATEGORY.

13. Paraboloid moved in orifice by float .... Discharge cannot be varied.
14. Disc or sphere moved in paraboloidal tube by float........ Discharge cannot be varied.
15. Pendulous obstruction moved and varied by velocity of passing water.................... Discharge cannot be varied.
16. Flat, cylindrical or other shaped valve with uniform motion derived from float, but with curved orifice or orifices...... Variable, in the latter case by closing off one or more orifices.
17. Rectangular aperture or apertures, in flat plate or cylindrical valve, susceptible of two rectilinear, or rotary and vertical movements, one differential and automatic; the other adjustable, to vary discharge.

The most self-evident forms of apparatus for attaining the end required belong to the first class. The Glenfield Jones, a simple surface-weir variety, is illustrated in Fig. 1, and it will be seen that the amount of discharge is regulated by varying the depth of submergence of the weir. This, however, is an imperfect type, as friction causes the weir to be more or less submerged, depending on whether it is floating on rising or falling water, and, furthermore, the adjustment for varying the discharge is cumbersome and inconvenient.

A better arrangement is that which is illustrated in Fig. 2, in which it will be seen that the substitution of a submerged form of weir reduces greatly the error due to friction, since difference of submersion has less effect. The adjustment of the discharge by the closure

AUTOMATIC MODULES,
WITH ADJUSTABLE DISCHARGE.

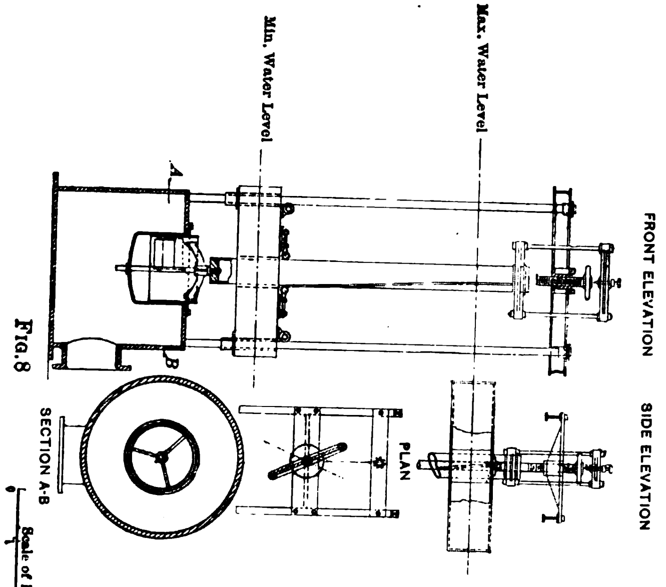

FIG. 8

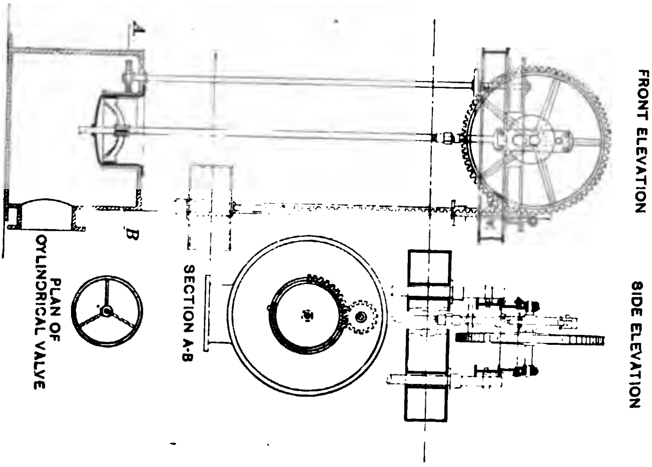

FIG. 9

of orifices is not only simpler, but lends itself to an easy method of indicating, on a graduated dial, the rate of discharge, seeing that the discharge is directly proportional to the amount of angular movement of the inner cylinder. This end may also be attained, with less friction, by the pneumatic device illustrated in Fig. 3; but the writer cannot say that this appears to him to be a hopeful form, on account of the difficulty of keeping the upper part of the siphon free from air.

To the second category belongs the constant-flow valve of Professor Fleming Jenkins, invented in 1876, of which Fig. 4 is an illustration.

A simpler form has been illustrated and described* by Professor W. R. Burton.

A difficulty encountered when trying a valve of this form, in Buenos Ayres some years ago, was the blithering set up, due to the constant oscillation of the valve about its mean position; but this could doubtless be overcome by a judicious damping arrangement.

Fig. 5 illustrates a somewhat different type of apparatus of the same class, which occurred to the writer on reading of an ingenious form of submerged weir-gauge constructed by Mr. John H. Tudsbery-Turner at the Yokohama water-works.

Class 3 needs no description, nor can the writer call to mind a single case in which this principle has been applied in practice.

A typical example of Class 4 is Juan Ribera's Spanish module, a form of which, designed by the late Mr. J. F. La Trobe Bateman for the City of Buenos Ayres Water-Works, is illustrated in Fig. 6. This would constitute an elegant solution of the problem, did the apparatus fulfil the first condition laid down. Unfortunately, it does not, as it is not susceptible of adjustment for varying the discharge for which it was designed; the popular idea that the discharge may be varied, without affecting the uniformity of the flow, by an initial alteration in the position of the cone in the diaphragm, being a delusion.

Fig. 7 illustrates Appold's module, the action of which depends on the dynamic effect due to variation of velocity. It is, therefore, necessarily inaccurate; and, furthermore, is not susceptible of adjustment for varying the discharge.

What the writer believes to be an original form of module occurred to him in 1893. The fundamental principle of this form consists in

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* *Minutes of Proceedings*, Inst. C. E., Vol. cxii, p. 393.

AUTOMATIC MODULES, WITH ADJUSTABLE DISCHARGE.

Scale

Inches 12 0 1 2 3 Feet

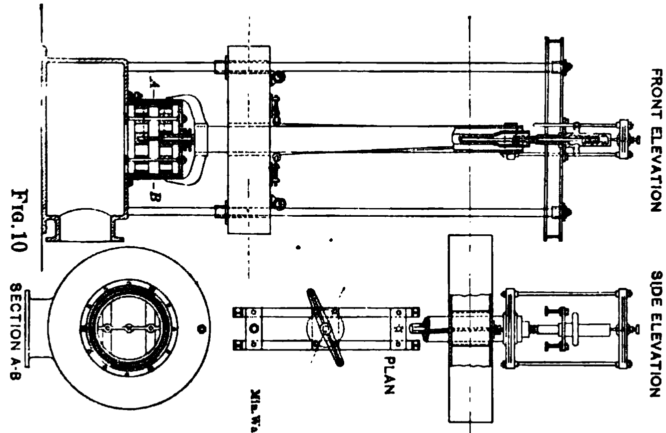

Fig. 10

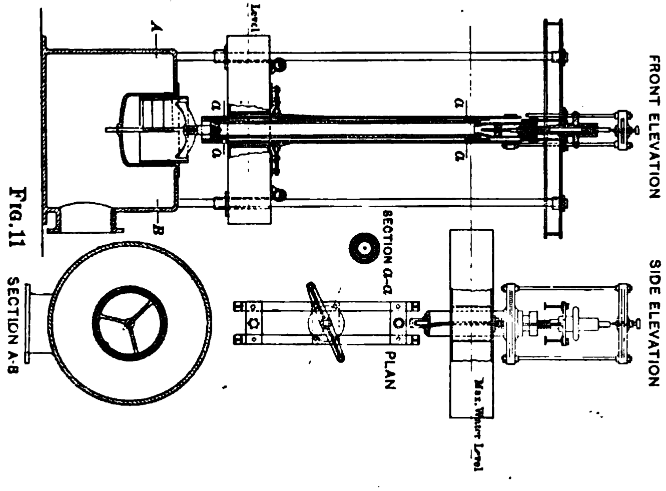

Fig. 11

the closing of a submerged orifice, or orifices, in two distinct directions, one automatic and differential, the other by hand to set to the discharge required. Fig. 8 shows the form in which the idea first occurred to the writer. It will be seen that the apparatus consists of two almost touching concentric cylinders, on opposite quadrants of each of which are cut two similar rectangular apertures, each occupying a little less than 90° of the circumference. The amount of opening is varied by the float, which causes the inner cylinder to rotate in the ratio of the square root of the head to which they are exposed. This is effected by means of a differential screw, planted or cut on the hollow central shaft, the development of which is part of a parabola. Fig. 9, which has already appeared in the correspondence on the City of Buenos Ayres Sanitary Improvement Works,* is the form which, for constructional reasons, best pleased the then Engineer in Chief of those works, Mr. Charles Nystromer.

It will be observed that the order of movements is the reverse of that which occurs in the first form, and that a cam has been substituted for the differential screw. It should be pointed out, however, that this arrangement, besides entailing greater mechanical complication, labors under the disadvantage of having more moving parts under water.

The form illustrated in Fig. 8 is not theoretically perfect, as in the adjustment for discharge the differential screw is lowered or raised in the guides of the float a distance twice as great as that traversed by the centroid of the apertures. Although this error, in all ordinary cases, is so small as to be negligible, it may be eliminated by either of the devices illustrated in Figs. 10 and 11; in the former by closing the orifices concentrically, in the latter by preserving constant the relative positions of the screw and of the centroid of the apertures.

As a matter of fact, however, the writer does not esteem these devices to be a real improvement on Fig. 8, which is his favorite form, since they entail greater complication, and inevitably give rise to an increase of friction.

As it may be objected that these modules would necessitate tedious calculation and difficult shopwork, in the shaping of the differential screw to meet each special case of change in the maximum and minimum depth of orifice, or range of water level, it may be pointed out that it would suffice to draw out, once for all, the development of the screw (which is a parabola, having its vertex at the center of the aperture), and take that portion of it comprised between the maximum and minimum water levels of the special case under consideration. It will thus be seen that the construction of these modules is no more difficult than that of ordinary sluice-valves, and that, therefore, they can be manufactured and stocked like any other ironwork.

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* *Minutes of Proceedings*, Inst. C. E., Vol. cxxiv, p. 86.

In conclusion, the writer hopes that the foregoing brief analysis of the various forms of automatic module which have come under his notice, or which he has evolved, may be found useful by members of the profession, when designing apparatus of a like nature.

Vol. XXIX. FEBRUARY, 1903. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

NOTE ON THE COEFFICIENT OF ELASTICITY OF CONCRETE AND MORTAR BEAMS DURING FLEXURE.*

By Myron S. Falk, Jun. Am. Soc. C. E.

A correct knowledge of the value of the coefficient of elasticity in the case of the flexure of steel-concrete, concrete or mortar beams is a matter of the greatest importance in the designing of beams of this character. The following notes give the results for concrete and mortar beams tested to the point of failure, and are perhaps of more than ordinary value on account of the age of the beams tested.

These beams were square in cross-section, measuring approximately 4 ins. on each side, and were about 38 ins. long. They were first broken by weights applied at the center of 36-in. spans, and then each half of the broken beam was again broken by weights applied at the center of 16-in. spans. The beams were made, during the summer and fall of 1895, by Mr. Adolph Black, Instructor of Civil Engineering in Columbia University, and were tested by the writer, in the Mechanical Laboratory of that University, on an Emery testing machine, in November, 1902.

The beams were four in number. Two were of gravel-concrete and two of mortar. Table No. 1 shows the ratio of gravel and sand to

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* This paper will not be presented for discussion at any meeting, but its discussion may be called up at any time, and written communications on the subject are invited for presentation to the Society and for subsequent publication.

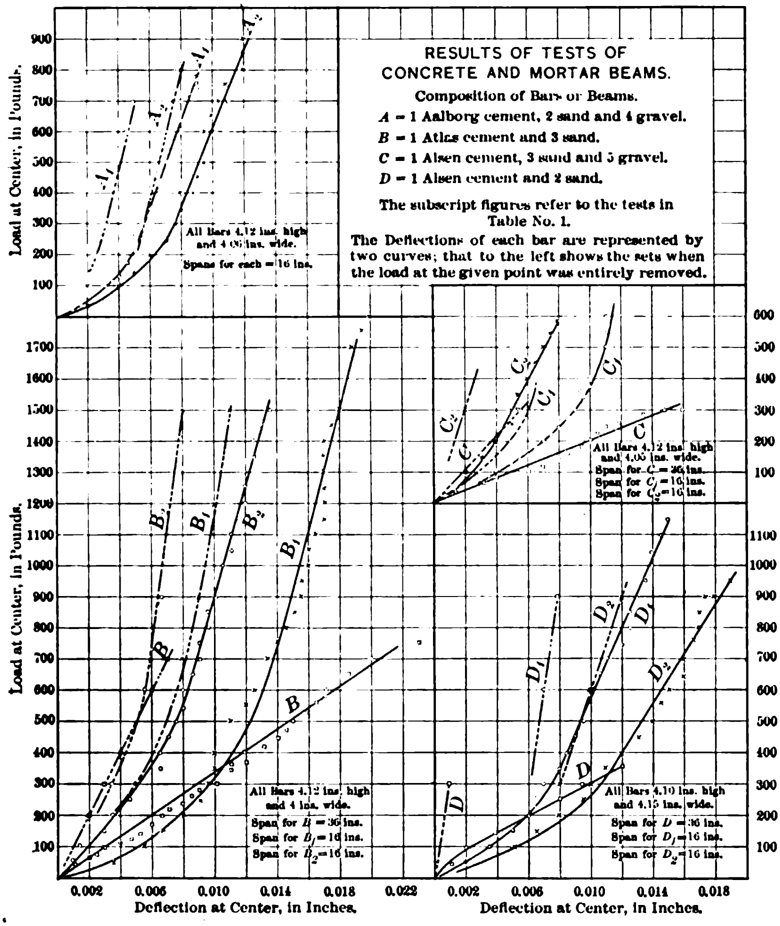
RESULTS OF TESTS OF
CONCRETE AND MORTAR BEAMS.
Composition of Bars or Beams.
A = 1 Aalborg cement, 2 sand and 4 gravel.
B = 1 Atlas cement and 3 sand.
C = 1 Alsen cement, 3 sand and 5 gravel.
D = 1 Alsen cement and 2 sand.
The subscript figures refer to the tests in Table No. 1.
The Deflections of each bar are represented by two curves; that to the left shows the sets when the load at the given point was entirely removed.
Load at Center, in Pounds.
900
800
700
600
500
400
300
200
100
A
A₁
A₂
All Bars 4.12 ins. high and 4.06 ins. wide.
Spans for each = 16 ins.
1700
1600
1500
1400
1300
1200
1100
1000
B
B₁
B₂
All Bars 4.12 ins. high and 4 ins. wide.
Span for B = 36 ins.
Span for B₁ = 16 ins.
Span for B₂ = 16 ins.
0.002
0.006
0.010
0.014
0.018
0.022
Deflection at Center, in Inches.
C
C₁
C₂
All Bars 4.12 ins. high and 4.06 ins. wide.
Span for C = 36 ins.
Span for C₁ = 16 ins.
Span for C₂ = 16 ins.
D
D₁
D₂
All Bars 4.10 ins. high and 4.15 ins. wide.
Span for D = 36 ins.
Span for D₁ = 16 ins.
Span for D₂ = 16 ins.
Deflection at Center, in Inches.

FIG. 1.

cement. The sand used was from Cow Bay, Long Island. It was sharp and clean, being entirely free from loam and organic matter. The gravel used was rounded, and varied in diameter from ¼ in. to 2½ ins. It was well washed before being used. Three kinds of cement were used, as shown by the table. The usual cement tests showed that the cement was standard in quality. The material was watered to such a consistency that, when solidly rammed in the moulds, water flushed the surface slightly. The material was allowed to remain in the moulds for 3 days, and it set in the air; during the first year the bars were watered at intervals of 10 days or two weeks; during the second year they were watered at intervals of about two months, and after that very intermittently. The bars were never exposed to the weather, being kept during the entire time under cover, in the basement of one of the University buildings. The deflections during the test were measured by a lever deflectometer, reading, by means of a vernier, to the thousandth part of an inch. The instrument was examined for errors before and after the tests, and was found to be correct for the range of readings used.

TABLE No. 1.

Bar.	Age, in years.	Span, in inches.	SECTION OF BAR, IN INCHES.		Coefficient of elasticity, in pounds per square inch.	Extreme fiber stress, in pounds per square inch.
			Depth.	Width.		
A	7.4	36	4.12	4.06	....	....
A_1	7.4	16	4.12	4.06	1 591 000	278
A_2	7.4	16	4.12	4.06	1 102 000	315
B	7	36	4.12	4.00	2 122 000	606
B_1	7	16	4.12	4.00	2 440 000	686
B_2	7	16	4.12	4.00	1 220 000	530
C	7	36	4.12	4.05	1 815 000	247
C_1	7	16	4.12	4.05	387 000	229
C_2	7	16	4.12	4.05	1 023 000	208
D	7.3	36	4.10	4.15	1 165 000	294
D_1	7.3	16	4.10	4.15	597 000	415
D_2	7.3	16	4.10	4.15	597 000	346

Bars A = 1 Aalborg cement, 2 sand and 4 gravel.
" B = 1 Atlas cement and 3 sand.
" C = 1 Alsen cement, 3 sand and 5 gravel.
" D = 1 Alsen cement and 2 sand.

The loads were applied at the intervals shown graphically on the diagrams. At different times the load was entirely removed in order that readings for the permanent deflections might be obtained. The readings were all taken about 15 seconds after the application or removal of the loads.

As shown by the diagrams, the strain of deflection consisted of two parts, one part apparently permanent and one part elastic, the latter disappearing upon the removal of the load. This is shown on the diagram for any one beam by the use of the same letter and subscript on two corresponding or mutually related curves.

The coefficient of elasticity was computed by using the difference between the two deflections thus found; in other words, the elastic deflection was used. This deflection was found to vary almost exactly as the center load, and could be represented by a straight line; no coefficient ef elasticity was computed for a center loading of less than 200 lbs.

The table also gives the values of the extreme fiber stress in the beam at the instant of rupture, the weight of the beam being allowed for in the computations. These values agree, with one or two exceptions, with the results obtained by other experimenters. An attempt was also made, using 4-in. cubes dressed from this material, to obtain a value for the coefficient of elasticity of concrete in compression. The blocks, however, were too small to permit of readings being taken directly from the sides of the specimen, and it was found that there was too much lost motion to permit of measurements being taken between the heads of the testing machine. The attempt to find these values was therefore abandoned. The ultimate resistance to compression of these cubes, when tested with plaster of paris beds, varied from 7 000 to 9 000 lbs. per square inch.

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THE SANITARY DISPOSAL OF MUNICIPAL REFUSE.

An Informal Discussion.*

By Messrs. Myron S. Falk, M. N. Baker, W. J. Baldwin and H. de B. Parsons.

Presented at the Meetings of December 17th, 1902, and January 7th, 1903.

Mr. Falk. **Myron S. Falk**, Jun. Am. Soc. C. E. (by letter).—Many and various have been the methods proposed for the sanitary disposal of municipal refuse. The complete destruction of the material, by means of heat generated by itself or by the aid of heat supplied from extraneous sources, has been the method most advocated. The first case brings into consideration the hope that power may be obtained from this waste material at the time of its destruction. In relation to this, and during this discussion, the plan of producing gas, and thus, indirectly, power, immediately from municipal wastes has not been considered; it is possible that mature reflection may reveal great inherent advantages to be derived from this method of disposal.

In the production of gas, as is well known, water in the form of steam is added to the gases produced from the destructive distillation of coal. It seems not at all unreasonable, therefore, in view of the large percentage of moisture contained in garbage, to expect that the introduction of garbage into a gas producer may not only be a direct saving in the fuel required, but may also obviate the necessity of adding live steam. It is true that, in the ordinary case of gas production, it is steam and not wet fuel which is added, but it is not unreasonable to expect that some method can be devised by which garbage may be placed in the producer at such times and in such a manner that its contained water may replace the water which must ordinarily be added. There is but little cause to doubt that such a plan may be put in successful operation, and it certainly seems to offer as great a possibility of obtaining power from wastes as any other plan heretofore proposed. Mr. Falk.

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* Continued from the *Proceedings* for January, 1903.

Mr. Baker. M. N. Baker, Esq.—It is very evident from the discussions that refuse disposal is a distinctively engineering problem; but, thus far, in America, it has rarely been recognized as such. It is to be hoped that the time is coming—in fact, that it has arrived—when there will be a much needed change, in this respect. There are, in this country, connected with the various companies who are building garbage furnaces or who are establishing reduction plants, comparatively few engineers engaged in the work.

It is a significant fact that, whereas our municipalities call in eminent engineers and spend money unstintedly for water supply and sewerage, only on one or two occasions have they called in an engineer to advise them in the matter of garbage disposal, and as far as entrusting to an engineer the whole problem of refuse collection and disposal it is doubtful whether a single instance could be named.

There is the valuable report on the Trenton investigation, mentioned by Mr. Horton, but it is yet to be heard that there have been any decided practical results from it. But, at Trenton, no engineer was called upon until after several years of blundering upon the subject; and, bad as Trenton is, as an example of neglect in this respect, it still remains a shining example of almost the only city in the country that has secured any engineering advice whatever.

One of the cities to adopt garbage cremation recently is Milwaukee. The contract for installing the furnaces provided that the contractor should guarantee that they could be operated with eighteen men, but it is stated that there are 79 or 80 on the pay roll at the present time. It is claimed that this is no fault of the furnaces, being a mere matter of affording employment to municipal laborers; but, however that may be, it serves as an illustration of the unsatisfactory condition of garbage disposal in this country, and of the need of employing engineers to design and operate garbage disposal works.

The low temperature in the Trenton furnaces is remarkable. In recent English installations the aim is to get as nearly as possible to a temperature of 1 800 or 2 000° Fahr. instead of 800 to 1 000 degrees.

Some interesting letters have appeared recently in the London *Electrician*—letters brought out by a paper* by W. F. Goodrich, Assoc.

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* "Electricity from Refuse—The Case for the Modern Destructor." A paper read before the Manchester Local Section of the Institution of Electrical Engineers, and published in abstract in *The Electrician* for November 28th, 1902. The letters mentioned appeared in the issues of the same journal for December 5th and 19th, 1902.

Mr. Baker. Inst. Mech. E., on a combination of refuse destructors (as they call them in England) and electricity works. Several of the writers of these letters, men in some instances who are operating combined refuse destructors and electricity works, have expressed themselves strongly in opposition to such a combination. Certainly, such opposition is a significant fact, and one that should be considered very carefully at the inception of garbage disposal as an engineering problem in this country.

Thus far in the discussion, comparatively little has been said regarding reduction as a means of garbage disposal. To present the subject fairly would take a large amount of time, but attention may be called to a fact which, perhaps, has already been mentioned, but only incidentally, that in all, or nearly all, the larger cities of the United States, which have any improved means of garbage disposal whatever, reduction is being used, and scarcely any of them are using cremation.

TABLE No. 1.—Cities of the United States, Having Populations of 200 000 or More, Where Improved Methods of Garbage Disposal Are Used.

	Population.	Improved means of disposal.
New York	3 437 202	Reduction.
Chicago	1 698 575	None.*
Philadelphia	1 293 697	Reduction.
St. Louis	575 238	Reduction.
Boston	560 892	Reduction.
Baltimore	508 957	None.†
Cleveland	381 768	Reduction.
Buffalo	352 387	Reduction.
San Francisco	342 782	Cremation.
Cincinnati	325 902	Reduction.
Pittsburg	321 615	Reduction.
New Orleans	287 104	None.
Detroit	285 704	Reduction.
Milwaukee	285 315	Cremation.
District of Columbia	278 718	Reduction.
Newark	246 070	None.*
Jersey City	206 433	None.
Louisville	204 731	Cremation.
Minneapolis	202 718	Cremation.

This does not necessarily imply that reduction in this country has been eminently successful and cremation has been a failure, but the figures do show that reduction is at least worthy of serious attention.

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* A small quantity of garbage is, or has been, cremated.

† Contract awarded, with the understanding that reduction will be used.

All the reduction plants are in the hands of private companies, and comparatively little satisfactory information regarding their financial success is available. Possibly before this discussion is closed it might be feasible to bring out some detailed information from persons familiar with reduction systems. Unquestionably, such information would add very materially to the value of this discussion, in which the many large reduction plants of the country have been virtually ignored. Mr Baker.

Statistics, collected by the speaker for his "Municipal Year Book," and revised to date, show that, of the nineteen cities (Table No. 1) of the United States having populations of 200 000 inhabitants or more in 1900, fourteen have some improved means of disposal, and, of these fourteen, ten depend on reduction and four on cremation. In addition, two other places have awarded contracts for final disposal, with the understanding that reduction will be used. Even if the list be extended to include places of 100 000 inhabitants or more, having improved means of disposal, there are but six with furnaces to fourteen with reduction plants, or sixteen of the latter if plants under contract are included. Taking into consideration all places of 3 000 population and more, there were, in 1902, a total of 74 crematories and 22 reduction works, all but three of the latter being in places of more than 40 000 population. Reduction is generally held to be impracticable in small cities, but the figures given show that in the United States that system prevails wherever it is feasible.

W. J. Baldwin, M. Am. Soc. C. E.—The speaker is wholly unprepared to talk on the subject of garbage cremation, for the reason that such cremation as he has been doing has been in another direction, *viz.*, either hospital refuse destruction, or waste fuel utilization. Mr. Baldwin.

Mr. Soper has suggested the matter of snow melting. There is a great deal of fun in the subject of snow melting, and, were it not that reference to it had been made, the speaker might refrain from alluding to it. The subject is very old, and should be well understood by engineers; still, it comes up, as in the present instance.

When Inspector Williams was made Commissioner of Street Cleaning of New York City, the *Sun* asked why he could not melt the snow off the streets over night, and not leave it to be shovelled and carted when the contractor got ready; and suggested the use of the fire engines of New York for this purpose. Of course, a technical paper would hardly propose such a thing, but Inspector Williams was exercised so much that he asked the speaker if there was anything in the suggestion. The speaker went to Professor Draper, of the Meteorological Department, and ascertained the amount of the snowfall for a certain storm in New York City, and then calculated the street areas, not including the housetops or back yards. A computation showed that it would take all the fire engines in New York City, running day and night, three years to burn coal sufficient to melt that

Mr. Baldwin. snowfall; that there would be 90 000 tons of coal to haul, and 20 000 loads of ashes left to cart away. The *Sun* would not publish this information, but it appeared in *The American Machinist*. Later, an experiment was made by Mr. Waring, in melting snow, in a manhole in the street, with a coil of pipe and a boiler, which showed the futility of such methods.

Experiences similar to these—steam-heated snow-ploughs, etc.—should set at rest the question of melting the snow, especially with steam, or even with direct fire. The computations were made on the supposition that all the steam generated could be brought in contact with the snow; but, as a matter of fact, in trying to melt snow by any kind of pans, or by blowing steam through it, probably not 10% of the steam would come in contact with the snow, and, in consequence, it would blow away. Again, evaporation will take heat not required for melting. It requires 142 B. T. U. to melt 1 lb. of snow from snow at 32° to water at 32°; but it requires more heat when the snow has a temperature of zero, additional heat to warm the water so that it will not freeze in running off, and heat—a great deal of heat—to vaporize the proportion of the water that will be vaporized.

In regard to particles, or sparks, that appear at the head of a chimney of a crematory, especially at night, they always appear as though they were luminous from heat, but investigation has proved that they were not always so; that immediately over the chimney these particles reflected the light of the chimney, and even when they passed a long distance—probably 20 ft. outside of the axis of the chimney—they would look as if they were afire; whereas, as a matter of fact, it was only the reflected light from the chimney. In an investigation leading to a determination of how far the sparks might fly, it was found that they were not actually sparks at all.

Again, there is the question of what might be done in the way of quenching sparks, assuming that they are sparks. With a chimney 100 ft. high, and having 1 000° of heat, there is a considerable upward push, which might be represented by 2 or 3 ins. of water pressure, and it is possible that something might be arranged at the top of such a chimney by which the sparks, smoke and gases could be given a slight dip into a water tank and thereby cooled.

Mr. Parsons has said that he thought this crematory or destructor could be made to operate without extra fuel. The speaker does not think this would be possible, as there is more than 80% of water in the vegetable and animal matter in garbage. A cabbage will contain more; and all ordinary albuminous compounds—meats and other refuse—contain so much water that the speaker cannot see how it is possible to do without the use of some fuel. Mr. Hering says that the water is evaporated first, or that the moisture is drained off in channels before the garbage is put upon the fire, and is then mixed with a large quantity of dry refuse—wood, straw, paper, etc.—and also a large quantity of unburned coal. Mr. Baldwin.

In that case, the solution seems to be that there is enough carbon present to evaporate the water, but still, in many cases, there is a great deal of water after the ordinary draining and drying is done. An ordinary dry cabbage contains 80% of water, and the water is very hard to destroy, but, of course, it is necessary to take all the material that comes from hotels and from kitchens, as that is what is to be destroyed. Now, the speaker is satisfied that what is collected in separate receptacles as garbage, in New York City, would contain 80% of water which would not run out by gravitation, and that about 10% of the original would have to be good carbon in order to evaporate the contained water.

The speaker would like to see an apparatus which will burn the ordinary garbage and admixture with dry refuse, or even with ashes. The ashes from an ordinary engineer's department amount to about 20%, by weight, of the coal put in the furnace, but in those ashes there is not 2% of coal. Now, there may be wood enough, in some cases, but, even in New York City, where will the necessary quantity come from ?

The speaker can show drawings and furnaces constructed for special work—not primarily for destroying garbage, except in a general way—but is interested in the construction of crematories, and would like to know more about the way to construct a furnace and get along without a primary fire and the addition of fuel.

Another point about cremating garbage, and the utilization of the heat therefrom under boilers, is the formation of various vapors, or gases, which are partially condensable when they strike the heating surface of a boiler. They may contain acids which will injure the boiler tubes to a considerable extent; and, in Europe, where they utilize the heat under boilers, presumably, the boilers are of a very simple type. It would be well for anyone who desires to utilize the heat from garbage and general refuse crematories to study the effect of such gases on the small tube boilers used so extensively in America.

Mr. Parsons. H. DE B. PARSONS, M. Am. Soc. C. E.—The problem before a City Commissioner, to dispose of the refuse of a municipality, is not always a scientific one. Usually, he has to face a practical problem. In New York City, the fault is due to the form of government and the contract system now in vogue. As a change cannot be made quickly, one has to do the best he can.

The scientific treatments of the wastes of a municipality are fairly well understood. The question is one of engineering; and an engineer who is willing to study the problem can dispose of those wastes in a manner which will be sanitary, provided, of course, that the municipality will give him, or will give the Commissioner, the money to carry out his plans.

Mr. Parsons. The wastes are being disposed of in Europe in a more scientific manner than in this country. The reason, probably, is that action was taken in America without previous scientific study. In Europe, they started with cremation. In America, they followed with cremation; but, as the cremation system adopted was false, failure followed, and, in many localities, public sentiment was set against it. This has been probably the chief reason that cremation is not more generally adopted on this side of the Atlantic.

In Europe, the collections are made and brought to a destructor, where they are cremated; and, in the most successful plants, they are cremated without the use of any fuel whatsoever, beyond the fuel supplied in the garbage and by the other wastes. Each collection district differs in the amount and character of its refuse, but there is sufficient combustible material collected which, when mixed with the garbage, will make it burn in a satisfactory manner.

The object sought, in the most successful plants, is to produce a high temperature; and a plant that will not produce a high temperature is not considered successful.

An incinerator or crematory, as the destructors are called in this country, which has to have a fume or stench cremator, is false in design, or else has that element put into the design in order to meet public sentiment. If the temperature in the burning furnace is sufficiently high, there is no need of a fume cremator. A fume cremator is simply a small fire placed either at the base of the stack, or somewhere in the passage of the gases, the idea being to burn up any fume-creating particles that might pass from the furnace before they reach the outside air.

In Europe, recent practice has not adopted a high stack, many successful furnaces being operated with a short stack and a forced draught. By a short stack is meant one of 70 to 80 ft., although some are still lower. Sufficient height should be given the stack to stop any question as to its being a source of annoyance or a nuisance. The earliest destructors used very tall stacks and natural draught.

Personally, the speaker favors the destruction of municipal refuse by cremation, and believes that it will be generally adopted in this country before a great many years have passed. As indicated before, persons have promoted furnaces, destructors, cremators and incinerators which were not designed scientifically, or have formed companies not strong enough, financially, to carry out their claims. Several cities have recorded failure from both these causes, and in some the destructors are now out of use.

There has been another cause of failure, due to the collection of garbage at the destructor. Garbage, when allowed to collect *en masse*, is extremely offensive; and, unless it is properly taken care of and promptly burned, is apt to create an adverse public sentiment, although the destructor itself may be good of its kind.

The system of reduction has been adopted by a number of our larger cities because it was easier to organize a reduction plant than a destructor plant. The fear of creating a nuisance—one of the causes most frequently mentioned—has acted to delay progress in the direction of cremation. The same cause, however, was not as active in the case of reduction. The returns from a reduction plant are not sufficient to operate it. Such a plant must rely upon a bonus from the city. The returns from properly constructed destructors, supplied with suitable municipal wastes, should enable the plant to be more than self-maintaining, and to earn a handsome income for the municipality. Mr. Parsons.

It is quite common in Europe to see small towns in which the actual pumping of the water supply is accomplished by means of the steam generated from the heat produced in the destructors. Some towns use the power for electric street-lighting, and others sell the electricity generated. It is perfectly possible to use the heat generated in a manner which will be income-earning, while the reduction plant needs to be sustained by a bonus.

Destructor plants will probably first be started by the smaller towns. On their success, which depends on proper engineering advice, the larger cities will slowly plan future improvements.

The practical problem in any city is the distance from the point of collection to the point of discharge of the carts. In some cities that haul is short, in others it is long. In New York City, some of the carts, the speaker believes, have hauls as long as five miles. A system of collection by automobiles has been discussed, but no automobile has yet been designed which would be sufficiently regular to stand the service. Perhaps, in time, such perfection may be reached as to warrant the collection by this means.

Snow-melting machines cannot handle the snow fast enough. If the carts could be regulated so that they would bring the supply just at the rated capacity of the machines, they might operate in a satisfactory manner; but the trouble is that all the carts arrive together. As they cannot stand in line with their loads of snow, they have to dump it, and if the machine cannot take it it is simply dumped on the street, which is just what is not wanted. When snow has lain in the street a little while, it becomes mixed with dirt and is then difficult to melt. Snow-melters have not proved economical, either in time or money.

If the snow is collected from the streets of New York City promptly, there is little objection to its being dumped in the river, as the snow is very clean. A great drawback has been the lack of docks from which snow could be dumped.

While Mr. Soper's remarks are interesting, some of his statements scarcely give due weight to the practical conditions as they exist in the City of New York.

Mr. Parsons. The speaker is sure that anyone studying the conditions as they exist in this city would conclude that the problem is less scientific than practical. In order to turn the practical problem into a scientific one requires time, and in time it will probably be done.

What all cities and all municipalities need is a co-operation between the different departments. The present Commissioner of the Department of Street Cleaning has done more than any other Commissioner in this direction. A Commissioner is hampered by the General City Government, of which he is but a part. The failure of some of the former administrations, to clean the streets and dispose of the refuse properly, may not have been due solely to the Commissioners.

No criticism of Mr. Soper's purpose is intended. His remarks seem to be misleading to members who have not made a specific study of the subject. His criticism of some of the former Commissioners is a little severe. While the results may have been as stated, it is possible that the Commissioners did not have the power to remedy those conditions.

The garbage of New York City contains an enormous amount of water, and the worst class of all to burn is the stuff collected from the fruit markets, as it is practically non-combustible, except by strong aids. Ordinary offal or kitchen garbage will burn reasonably well when mixed with the other wastes.

The rubbish collections in New York City are 95% combustible; the ashes from the private houses and small apartment houses contain about 20% of unburned coal. If the rubbish collections and the ash collections from private houses and small apartment houses are mixed with the garbage, the whole can be burned in a suitable furnace.

The ashes from the steam-heating companies and large manufacturing plants, known as "steam ash," are collected and brought to the dumps in separate vehicles, so that there is no necessity at any time of ever passing such ash through a destructor, because that ash is practically pure.

In Europe, the principal system of collection is one of non-separation. They simply collect the whole of the refuse, and this, just as it comes, goes into the destructor.

Most destructors contain some form of what is called a "drying table." The material as collected, either wet by contained moisture, or wet by rainfall, is placed first upon some part of the cell or furnace where it can be warmed, and is gradually passed back over the fire, in a manner similar to the coking method of firing. When the material has become dry, it is forced back to the hottest part of the grate, where it burns rapidly, supplying heat to dry the incoming material, while sufficient heat is left to evaporate, in boilers, according to the material burned, from 1 to 2 lbs. of water per pound of refuse.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XXIX. No. 3.
MARCH, 1903.

Edited by the Secretary, under the direction of the Committee on Publications.

Reprints from this publication, which is copyrighted, may be made on condition that
the full title of Paper, name of Author, page reference, and date
of presentation to the Society, are given.

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Papers and Discussions......Pages 225 to 338.

NEW YORK 1903.

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American Society of Civil Engineers.

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THE PRESIDENT OF THE SOCIETY IS *ex-officio* MEMBER OF ALL COMMITTEES.

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◆

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER, - - - 533 Columbus.
CABLE ADDRESS, - - - - "Ceas, New York."

Vol. XXIX. MARCH, 1903. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

SOCIETY AFFAIRS.

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March 4th, 1903.—The meeting was called to order at 8.50 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, 96 members and 28 guests.

The minutes of the Annual Meeting, and of the meetings of February 4th and 18th, 1903, were approved as printed in *Proceedings* for February, 1903.

Messrs. R. A. MacGregor and F. F. Harrington were appointed tellers to canvass the vote on the proposed amendment to the Constitution.

A paper entitled "A High-Voltage Power Transmission," by M. H. Gerry, Jr., Assoc. M. Am. Soc. C. E., was presented by the Secretary, and discussed by Messrs. F. O. Blackwell, P. H. Thomas, W. B. Potter and J. R. McKee.

The tellers appointed to canvass the ballots on the proposed amendment to the Constitution, relating to the method of election of members,* reported as follows:

Total number of ballots received		447
Not entitled to vote	2	
Ballots not signed	9	
	—	11
		436
Voted aye	401	
Voted nay	26	
Blank	9	
	—	436

The President announced that the proposed amendment was carried, as it had received an affirmative vote of more than two-thirds of all ballots cast, as provided by the Constitution (Sec. 5, Art. IX).

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Frank Harvey Eno, Columbus, Ohio.
Harry Foote Hodges, Washington, D. C.
William Benjamin Jackson, Madison, Wis.
Albert Ferdinand Reichmann, Chicago, Ill.
Junnosuke Yamaguchi, Kobe, Japan.

As Associate Members.

Maurice Fritchley Brown, Boston, Mass.
George Edward Howe, Glens Falls, N. Y.
Arthur Benjamin Ilsley, Boston, Mass.
Frederic Arnold Kummer, New York City.
William Sutton McFetridge, Parkersburg, W. Va.
Takejiro Shima, New York City.
Albert Franklin Sickman, Holyoke, Mass.
Everett Broomall Wilson, Newark, N. J.

The Secretary announced that at the meeting of the Board of Direction, March 3d, 1903, the reconsideration ballot, on the application of Frank Taylor Chambers, Assoc. M. Am. Soc. C. E., for transfer to the grade of Member, was canvassed, and that Mr. Chambers was elected a Member.

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* See *Proceedings*, Vol. XXIX, p. 86.

The Secretary announced the election of the following candidates by the Board of Direction on March 3d, 1903:

AS JUNIORS.

BRUCE BORLAND, Three Lakes, Wis.
CHARLES FRANK CLASS, Philadelphia, Pa.
JOHN CLAUSNITZER, New York City.
ROSSITER RAYMOND FERNOW, Ithaca, N. Y.
HARRY MACY HARPS, Fort Dodge, Iowa.
CALEB HYATT, Scarsdale, N. Y.
JOHN DOUGLAS MATHESON, New York City.

Adjourned.

March 18th, 1903.—The meeting was called to order at 8.45 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, 126 members and 17 guests.

A paper entitled, "Sand-Blast Cleaning of Structural Steel," by George W. Lilly, Assoc. M. Am. Soc. C. E., was presented by the author.

Written discussions on the paper from Messrs. Charles E. Fowler, William A. Polk and J. P. Snow were presented by the Secretary.

The subject was discussed verbally by Messrs. Theodore Belzner, Theodore Paschke, A. H. Sabin, Henry B. Seaman and the author.

The Secretary announced the death of the following members:

ALFRED L. RIVES, elected Member September 4th, 1872; died February 27th, 1903.

BENJAMIN HARRISON FLYNN, elected Junior October 2d, 1900; died March 1st, 1903.

WILLIAM BUEL FRANKLIN, elected Member April 1st, 1874; died March 8th, 1903.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

March 3d, 1903.—8.35 P. M.—President Noble in the chair; Chas. Warren Hunt, Secretary, and present, also, Messrs. Briggs, Craven, Croes, Davison, Knap, Kuichling, Osgood, Pegram, Schneider and Wilgus.

The seven geographical districts, into which the membership of the Society is divided, were established for the next year, the same as in 1902.

The resignation of E. H. Goodman, Assoc. Am. Soc. C. E., was accepted.

The following Committee to take charge of the local arrangements for the Thirty-fifth Annual Convention, to be held at Asheville, N. C., was appointed: Messrs. J. L. Ludlow, William Cain, George W. Frank, William Moncure, J. Imbrie Miller, W. B. W. Howe, Arthur Pew, E. T. D. Myers, Wilbur F. Foster, J. A. Montgomery.

Ballots on the reconsideration of the ballot on the application of Frank T. Chambers, M. Am. Soc. C. E., for transfer to the grade of Member, were canvassed, and Mr. Chambers was elected a Member.

Applications were considered, and other routine business transacted.

Seven candidates for admission as Junior were elected.*

Adjourned.

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* See page 101.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, April 1st, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and two papers will be presented for discussion, as follows: "The Filtration Works of the East Jersey Water Company, at Little Falls, New Jersey," by George W. Fuller, Assoc. M. Am. Soc. C. E.; and "Automatic Modules for Regulating the Speed of Filtration," by Charles Anthony, Jr., M. Am. Soc. C. E. These papers were printed in *Proceedings* for February, 1903.

Wednesday, April 15th, 1903.—8.30 P. M.—At this meeting a paper, by Sherman M. Turrill, Assoc. Am. Soc. C. E., entitled "An Investigation of the Properties of Brick Under Different Physical Conditions," will be presented for discussion. This paper is printed in this number of *Proceedings.*

Wednesday, May 6th, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and two papers will be presented for discussion, as follows: "A Small Rock-Fill Dam," by H. deB. Parsons, M. Am. Soc. C. E.; and "Deflection of Beams with Variable Moments of Inertia," by C. W. Hudson, M. Am. Soc. C. E. These papers are printed in this number of *Proceedings.*

ANNUAL CONVENTION OF 1903.

The Thirty-fifth Annual Convention of the Society will be held at Asheville, N. C., during the week beginning June 8th, 1903. The following have been appointed as a Local Committee of Arrangements:

J. L. Ludlow,
William Cain, W. B. W. Howe,
George W. Frank, Arthur Pew,
William Moncure, E. T. D. Myers,
J. Imbrie Miller, Wilbur F. Foster,
J. A. Montgomery.

TOPICS FOR DISCUSSION AT THE ANNUAL CONVENTION.

At the last four Annual Conventions no formal papers have been presented, but, instead, topics of general interest have been discussed. The interest which these discussions have aroused has shown that they are appreciated, and, for the coming Convention, the Committee on Publications would be glad to receive from members suggestions as to suitable topics.

The following list, of the subjects which have already been discussed at Conventions, is here printed, in order to give some idea of the kind of subjects desired:

LIST OF SUBJECTS PRESENTED FOR DISCUSSION AT THE LAST FOUR ANNUAL CONVENTIONS.

" Should the use of the method of Wheel Concentrations be discontinued in determining the Stresses in Railroad Bridges?

" In view of present knowledge of the Effect of Repeated Applications of Load, should Fatigue Formulas be used in Bridge Design?

" (*a*) Should Stream Contamination by the Sewage of Cities be absolutely prohibited by law?

" (*b*) Should the Purification of the Sewage of Cities be compulsory, and is this feasible for Large Cities?

" (*c*) Is Filtration the coming solution of the Pure-Water Question for Cities?

" What is the Proper Friction Coefficient for use in the design of Riveted Steel Pipe?

" What are the economic conditions under which Electricity may be profitably substituted for Steam in the operation of Branch Railroad Lines, and what are the engineering requirements to be considered in such substitution?

" What is the present development of the so-called Telferage System for moving either Freight or Passengers? What are the conditions under which that System is preferable to movement by Rail, and what is its adaptability to still further application in competition with Rail Lines?

" Height of Buildings.
  (1) What considerations should limit the height of buildings?
  (2) Do recent developments in construction, sanitation, intercommunication and economy of administration, warrant the removal of all restrictions?

" Recent Practice in Rails.
  The progressive increase in weight; the increase in hardness, particularly in carbon; the sections in most general use; the effect of changes in weight, composition and section.

" Filtration of Water for Public Use.
  The several processes now used for the removal of objectionable matter; their comparative sanitary effect, cost and reliability.

"Do the interests of the profession, and the duty of its members to the public, require that only those who are competent be allowed to practice as Civil Engineers? Under what authority, through what agency, and upon what evidence of competency, should applicants be admitted to the practice of Civil Engineering?

"Steel-Concrete Construction.

What stress in tension and compression should be allowed in concrete?

What is the proper modulas of elasticity of concrete?

In Steel-Concrete Arches:

(1) What should be the ratio of steel section to concrete section, and what is the best form and disposition of the former?

(2) What consideration should be given to temperature changes and consequent stresses?

(3) What are the best proportions for concrete, and what is the best method of placing it?

"The Decolorization of Water.

When is it necessary? How may it be accomplished?

"The Consumption of Water in Municipal Supplies and the Restriction of Waste.

"In contract work, either public or private, is it preferable to make separate contracts for the different branches of trades involved, or to combine all under one general contract?

"Is it possible and desirable to keep accounts of work in progress in such a manner as to ascertain unit costs on each class of work?

"Is steel susceptible of being made as permanent a building material as masonry?

"In view of the numerous disasters caused by the contracting of channels, or the damming of small streams, should non-navigable streams be under the control of the National Government?

"Should the National Government undertake the construction and operation of irrigation works?

"Should Engineering Practice be regulated by a code of ethics? If so, how can such a code be established?"

ACCESSIONS TO THE LIBRARY.

From February 11th to March 10th, 1903.

DONATIONS.*

LATHES, SCREW MACHINES, BORING AND TURNING MILLS.

A Practical Treatise on the Design and Construction of Turning Machines, Including Lathes, Automatic Screw Machines, Boring and Turning Mills, and their Accessories. By Thomas R. Shaw. Cloth, 9 x 6 ins., 10 + 649 + 5 pp., illus. The Scientific Publishing Company, Manchester, 1903. 15 shillings, net.

The object of this work is to review in detail types of the many varied machine tools in use for the working into shape of metals, and to give constructive details of the more important mechanisms and devices, which, it is hoped, will prove helpful to those engaged in various branches of engineering, and make easier the solution of problems in design which are presenting themselves continually in various guises in every-day practice. It was considered that the best way to treat the subject would be to give examples from actual practice, showing the different mechanisms with their respective constructional surroundings. This plan has been adopted as far as practicable. The Contents are: General Notes on Design and Arrangement; Principle of the Lathe; Small Lathes with Some Special Features; On Screw Threads; American Lathes; Lathes for Special Purposes; Small Lathes for Accurate Work; Electrically-Driven Lathes; Summary of Lathe Design; Turret Lathes; Examples of Hollow Turrets; Vertical Turret Lathes; Full Automatic Screw Machines; Heavy Lathes; Boring and Turning Mills. There is an index of five pages.

IRON AND STEEL, IRON ORE, AND COAL STATISTICS FOR THE UNITED STATES, GREAT BRITAIN, GERMANY, FRANCE, AND BELGIUM.

Revised to the end of 1901. By James M. Swank. Cloth, 6 x 4 ins., 32 pp. Philadelphia, The American Iron and Steel Association, 1902.

This compilation of Iron and Steel, Iron Ore, and Coal Statistics for the United States and four European countries is presented to the members of the American Iron and Steel Association as a souvenir of the completion of the author's thirty years of continuous service, first as Secretary and afterwards as General Manager of the Association. The pamphlet also contains the production of iron ore in Algeria as far back as authentic statistics are available, the production of coke in the United States to the close of 1901, and of the shipments of Connellsville and Pocahontas Flat Top Coke, statistics of the shipments of Lake Superior iron ore and of Cuban iron ore to the same date; also complete statistics of the imports of iron ore into the United States at the close of 1901.

ENGINEERING CONTRACTS AND SPECIFICATIONS

Including a Brief Synopsis of the Law of Contracts, and Illustrative Examples of the General and Technical Clauses of Various Kinds of Engineering Specifications. Designed for the Use of Students, Engineers, and Contractors. By J. B. Johnson, M. Inst. C. E., M. Am. Soc. C. E., M. Am. Soc. M. E. Third Edition Revised. Cloth, 9 x 6 ins., 566 pp., por. Engineering News Publishing Co., New York, 1903. $6.00.

The preface states that in the present edition a general revision of Part IV has been made, in addition to minor changes in the other portions of the book. Several complete specifications have been entirely changed, or replaced, and many new ones have been added. Two new appendices are given on The Engineer as an Expert Witness, and the Standard Specifications for Iron and Steel proposed by the American Committee of the International Association for Testing Materials. By these additions the book has been enlarged 114 pages. The Parts are: Synopsis of the Law of Contracts; Engineering Specifications and Accompanying Documents; Specific Descriptive, or Technical Clauses in Specifications; Illustrative Examples of Complete Contracts and Specifications. There is an index of six pages.

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* Unless otherwise specified, books in this list have been donated by the Publishers.

STATICS BY ALGEBRAIC AND GRAPHIC METHODS.

Intended Primarily for Students of Engineering and Architecture. By Lewis J. Johnson, Assoc. M. Am. Soc. C. E. Cloth, 9 x 6 ins., 8 + 133 pp., 6 plates, illus. New York, John Wiley & Sons, 1903. $2.00.

It is stated in the preface that this volume has been written in the hope of helping students to acquire a knowledge of statics which will include the power to apply it correctly in professional work. To this end an attempt has been made to carry out several specific purposes, among which are the following: 1. To give much attention to the starting points of the science, and to make as clear as possible the course of deduction therefrom. 2. To point out the inherent mathematical limitations of pure statics, and to show how all its important problems are solved. 3. To develop algebraic and graphic methods of solution side by side, and with equal thoroughness. 4. To present a graded set of problems illustrating not only universal principles, but also how statics is used in engineering practice. The chapter headings are: Definitions and Preliminaries; Notation and Conventions; Parallelogram of Forces and its Derivatives; Algebraic and Graphic Statements of the Condition of Equilibrium, with Applications; Scope of Pure Statics; Solutions of Statical Problems; Additional General Topics and Processes; Centers of Gravity; Stress; Structures: Stresses in Non-Framed Structures; Stresses in Framed Structures; Additional Topics and Examples.

LIME AND CEMENT INDUSTRIES OF NEW YORK.

By Heinrich Ries. Chapters on the Cement Industry in New York. By Edwin C. Eckel. Cloth, 10 x 7 ins., pp. 641-968, 102 plates. Albany, University of the State of New York, 1901. (Bulletin of the New York State Museum, No. 44, Vol. 8. November, 1901.) (Donated by F. J. H. Merrill.)

The Contents are: Origin of Limestone; Chemical Composition; Geologic Occurrence; Prospecting; Color of Limestone; Mineralogic Composition; Uses of Limestone; Uses of Lime; Cement; Geology of New York Limestones; Limestone Occurrence by Counties; Cement Industry in New York State; Producers of Lime and Natural Cement; Producers of Natural Rock Cement; History of the Portland Cement Industry in New York State; Manufacture of Portland Cement in New York State; Tests of Cements, Made by the State Engineer, 1897-1900; Key to Tables of Limestone Analyses; Tables of Limestone Analyses. There is an index of ten pages.

Gifts have also been received from the following:

Am. Soc. Mech. Engrs. 1 pam., 8 bound vol.
Assoc. Amicale des Anciens Élèves de l'École Centrale. 1 vol.
Assoc. of Ry. Supts. of Bridges and Buildings. 1 pam.
Augusta, Ga.—City Council. 1 pam.
Binghamton, N. Y.—Water Commrs. 1 pam.
Boggs, John I. 8 bound vol.
Delaware, Lackawanna & Western R. R. Co. 2 pam.
Eng. Assoc of the South. 1 pam.
Fitchburg, Mass.—City Engr. 1 pam.
Great Britain—Patent Office. 10 pam.
Hutton, N. H. 1 pam.
Inst. of Civ. Engrs. 2 bound vol.
Johnstown, N. Y.—Board of Water Commrs. 1 pam.
Königliche Technische Hochschule zu Berlin. 1 pam.
Kummer, F. A. 1 bound vol.
Leominster, Mass.—Water Board. 1 pam.
Marburg, Edgar. 1 vol.
Marston, A. 1 pam.
Middletown, Conn.—Board of Water Commrs. 1 pam.
Midland Ry. Co. 1 pam.
Min. Soc. of Nova Scotia. 1 pam.
N. J.—Commr. of Pub. Roads. 1 bound vol.
New York Univ. 1 vol.
Northampton, Mass.—Water-Works. 1 pam.
Paine, Charles. 1 vol.
Pharr, H. N. 1 pam.
Platt, T. C. 4 pam.
Royal Soc. of New South Wales. 1 vol.
Sherman, Chas. W. 1 pam.
Simla, India—Director of Ry. Construction. 2 bound vol.
Soc. Belge des Ingénieurs et des Industriels. 1 pam.
U. S. Bureau of Statistics. 1 bound vol.
U. S. Commr. of Education. 1 bound vol.
U. S. Corps of Engrs. 28 specif.
U. S. Interstate Commerce Comm. 1 pam.
U. S. Office of Naval War Records. 7 pam.
Victoria—Water Supply Dept. 1 bound vol.
Webster, Albert L. 1 bound vol.
Young Men's Christian Assoc. of N. Y. 1 pam.

BY PURCHASE.

Der Brückenbau. Von Franz Tschertou. Wiesbaden, C. W. Kreidel, 1903.

Konstruktionslehre der einfachen Maschinenteile. Von O. v. Grove. 2 vol. Leipzig, S. Hirzel, 1902.

Das Eisenbahngleis. Von A. Haarmann. Kritischer Teil. Leipzig, Wilhelm Engelmann, 1902.

Der Praktische Maurer. (Maurer- und Steinmetzarbeiten). Ein Hand- und Nachschlagebuch aus der Praxis für die Praxis. Von Dr. E. A. Menzel. 12. vielfach verbesserte und vermehrte Auflage. Herausgegeben von Otto Alisch, A. Eckardt, Martin Köster, P. Schmidt. Leipzig, I. I. Arnd, 1902.

Elasticität und Festigkeit. Die für die Technik wichtigsten Sätze und deren erfahrungsmässige Grundlage. Von C. Bach. Vierte, vermehrte Auflage. Berlin, Julius Springer, 1902.

Experimental Engineering and Manual for Testing. For Engineers and for Students in Engineering Laboratories. By Rolla C. Carpenter. Fifth Revised and Enlarged Edition. New York, John Wiley & Sons; London, Chapman & Hall, Limited, 1902.

SUMMARY OF ACCESSIONS.

From February 11th to March 10th, 1903.

Donations (including 8 duplicates)	97
By purchase	7
Total	104

MEMBERSHIP.

ADDITIONS.

MEMBERS.

		Date of Membership
Chambers, Frank Taylor Civ. Engr., U. S. Navy, U. S. Navy Yard, Philadelphia, Pa	Assoc. M. M.	April 6, 1898 Mar. 3, 1903
Cooley, Maurice Wurtz Mgr., The National Contr. Co., 246 First St., Cambridge, Mass	Assoc. M. M.	Mar. 7, 1894 Dec. 3, 1902
Datesman, George Elvin Prin. Asst. Engr., Bureau of Surveys, 416 City Hall, Philadelphia, Pa		Feb. 4, 1903
Hodges, Harry Foote Maj., Corps of Engrs., U. S. A., 1812 N St., N. W., Washington, D. C		Mar. 4, 1903
Jackson, William Benjamin Madison, Wis		Mar. 4, 1903
Randolph, Isham Chf. Engr., San. Dist. of Chicago, Room 1010, Security Bldg., Chicago, Ill		Feb. 4, 1903
Reichmann, Albert Ferdinand Asst. Engr., Western Div., Am. Bridge Co., 1318 Monadnock Bldg., Chicago, Ill	Jun. Assoc. M. M.	April 30, 1895 Oct. 5, 1898 Mar. 4, 1903

ASSOCIATE MEMBERS.

Brown, Maurice Fritchley Chf. Engr.. Boston Bridge Works, 47 Winter St., Boston, Mass		Mar. 4, 1903
Brynn, Per Care, Am. Bridge Co., 51st St., Pittsburg, Pa		Feb. 4, 1903
Howe, George Edward Asst. Engr., Hudson River Water Power Co., Glens Falls, N. Y		Mar. 4, 1903
Howe, Joseph Milton Houston, Tex		Feb. 4, 1903
McFetridge, William Sutton Asst. Chf. Engr., Little Kanawha R. R. Co., Parkersburg, W. Va	Jun. Assoc. M.	May 3, 1898 Mar. 4, 1903
Paine, Hibbard Atwill Res. Engr., C., O. & W. R. R., Chandler, Okla. T		Feb. 4, 1903
Ross, Thomas Alexander Engr. in Chg., Shanghai Woosung Ry. Extension, Box 185, British P. O., Shanghai, China		Dec. 3, 1902
Sickman, Albert Franklin Holyoke, Mass		Mar. 4, 1903

	Date of Membership
Stayton, Edward Moses	
423 East Kansas St., Independence, Mo	Feb. 4, 1903
Wickes, Edward Dana	
Min. Engr., The Low Moor Iron Co. of Va., Low Moor, Va	Dec. 3, 1902
Wilson, Everett Broomall	
200 Peshine Ave., Newark, N. J	Mar. 4, 1903

ASSOCIATES.

Bernegau, Rudolf Caspar Carl Marie	
Treas., Keuffel & Esser Co., 127 Fulton St., New York City	Feb. 3, 1903

JUNIORS.

Adey, John Seager	
445 Lenox Ave., New York City	Feb. 3, 1903
Borland, Bruce	
2027 Prairie Ave., Chicago, Ill	Mar. 3, 1903
Cetti, Carolus Hermann Zane-	
Fort Worth, Tex	Feb. 3, 1903
Class, Charles Frank	
2610 North Jessup St., Philadelphia, Pa	Mar. 3, 1903
Crook, John Anthony	
Chf. Engr., The John Gilligan Co., Falls City, Nebr.	Feb. 3, 1903
Hyatt, Caleb	
Scarsdale, N. Y	Mar. 3, 1903
Kauffman, Vernet Albert	
Care, H. A. Sumner, Majestic Bldg., Denver, Colo	Feb. 3, 1903
Quanz, Rudolph	
507 Central Ave., Brooklyn, N. Y	Sept. 2, 1902
Smith, George Edson Philip	
Prof. of Physics and Eng., Univ. of Arizona, Tucson, Ariz.	Feb. 3, 1903
Stepath, Charles Underhill	
154 West 122d St., New York City	Feb. 3, 1903
Walker, Edward Lloyd	
Care, Jersey City Water Supply Co., 158 Ellison St., Paterson, N. J	Feb. 3, 1903

CHANGES OF ADDRESS.

MEMBERS.

Barber, William Davis..........Asst. Engr. in Chg., Div. of Constr. and Repairs, 323 City Hall, Chicago, Ill.

Beardsley, James Wallace .....Cons. Engr. to the Comm., and Chf. of the Bureau of Eng., Palace, Manila, Philippine Islands.

Coombs, Stephen Elbridge......4025 McPherson Ave., St. Louis, Mo.
Davis, Charles E. L. B.........Lt.-Col., Corps of Engrs., U. S. A., Chf. Engr. Officer of the Div., Manila, Philippine Islands.
Dunn, Daniel Burke............Care, S. A. L. Ry., Dallas, Ga.
Gates, Horace Delphos........ Asst. to City Engr., 311 Lyon St., San Francisco, Cal.
Hayden, William Wallace .....Asst. Engr., Y. & M. V. R. R., Poplar St. Depot, Memphis, Tenn.
Hurry, Edward Henry..........1 Broadway, Room 122, New York City.
Ingalls, Owen Lovejoy.........City Engr., Manila, Philippine Islands.
Kleinbeck, August Gustave.....710 North State St., Litchfield, Ill.
Linville, Jacob Hays...........Evergreen Lodge, Lansdowne, Pa.
MacNaughton, James............Care, MacIntyre Iron Co., 26 Cortlandt St., New York City.
Miller, Charles Henry........Engr. with McClintic-Marshall Const. Co. of Rankin, Pa.; 727 East End Ave., Pittsburg, Pa.
Parker, Harold ....South Lancaster, Mass.
Pew, Arthur....................Auburn, Ala.
Smith, William Charles........With Richards-Lundeen Co., Gen. Contrs., Minneapolis, Minn.
Stanford, Homer Reed..........Civ. Engr., U. S. N., Care, Bureau of Yards and Docks, Navy Dept., Washington, D. C.
Stanton, Robert Brewster .....66 Broadway, New York City.
Tomlinson, Sam.................1 Raffles Pl., Singapore, Straits Settlements.
Townsend, Curtis McDonald....Maj., Corps of Engrs., U. S. A., Manila, Philippine Islands.
Trundle, Horatio Hartley......Mocksville, Davie Co., N. C.
Value, Beverly Reid...........Care, Toronto & Niagara Power Co., Niagara Falls, Ont., Canada.
Watson, William Parsons.......Prin. Asst. Engr., Mo. Pac. Ry. Co., St. Louis, Mo.
Webb, George Herbert.........Asst. Engr., Michigan Central R. R., Kalamazoo, Mich.
Williams, Cyrus John Richard..Engr., Lyttelton Harbour Board, Christchurch, New Zealand.
Yates, Preston King............First Asst. Engr., The Lake Shore & Michigan Southern R. R., 67 Spangler Ave., Cleveland, Ohio.

ASSOCIATE MEMBERS.

Bance, Charles William........Asst. Engr., Jersey City Water Supply Co., 156 Ellison St., Paterson, N. J.
Boggs, John Innerarity.........Chf. Engr., Arkansas Southwestern Ry., Gurdon, Clark Co., Ark.

Boright, William Parsons......Care, T. H. Riddle Constr. Co., Ravenna, Ohio.

Carlile, Thomas Jenks..........Engr., Beaver Creek R. R. & Lumber Co., Davis, W. Va.

Cunningham, Joseph Hooker....Res. Engr., Puget Sound Power Co., Tacoma, Wash.

Edwards, Frederick............Asst. Prof. of Civ. Eng., Union Coll., Schenectady, N. Y.

Fain, James Rhea...............Norfolk, Nebr.

French, Frank Chauncey........Belen, N. Mex.

Henry, Philip Walter..........Vice-Pres., Medina Quarry Co., 150 Nassau St., New York City.

Moore, Charles Gillingham.....189 Cleveland Ave., Buffalo, N. Y.

Newberry, Spencer Baird.......Gen. Mgr., Sandusky Portland Cement Co., Bay Ridge, Ohio.

Nichols, Henry Francis.........Gen. Mgr. and Engr., James Hill & Sons, 63 Grenfell St., Adelaide, South Australia.

Noble, Frederick Charles......439 West 123d St., New York City.

Olberg, Charles Real..........Asst. Engr., U. S. Geological Survey, Washington, D. C.

Phillips, Howard Crathorne....Engr., Western Grand Div., A., T. & S. F. Ry., La Junta, Colo.

Rosewater, William Marcus....Chf. Draftsman, The Bucyrus Co., Gen. Delivery, Pittsburg, Pa.

Schenk, Carl Louis Eduard.....Contr. Engr., Exeter Machine Works, Rural Route No. 2, Oakdale, Pa.

Taber, George Aymar...........Asst. Engr., Rapid Transit R. R. Comm., 312 West 122d St., New York City.

Turner, George Dallas Baird...Vice-Pres. and Gen. Mgr., J. I. C. Mining & Milling Co., 317 Atlas Blk., Salt Lake City, Utah.

ASSOCIATES.

Turrill, Sherman Marsh........New Milford, Conn.

JUNIORS.

Armstrong, Alexander Floyd...Office of City Engr., Manila, Philippine Islands.

Dimond, James Renwick.........128 West 33d St., New York City.

Fuller, Carl Hamilton..........Eng. Dept., Koken Iron Works, St. Louis, Mo.

Pearse, Langdon.................177 Sixth Ave., Brooklyn, N. Y.

Perring, Henry Garfield.......Draftsman, Phila. Rapid Transit Co., 619 North 48th St., Philadelphia, Pa.

Thompson, Wilford Ashford....Engr., Imperial Constr. Co., Brawley, *via* Imperial, Cal.

RESIGNATIONS.

ASSOCIATES.

	Date of Resignation.
Goodman, Edward Harris	March 3d, 1903

DEATHS.

Flynn, Benjamin Harrison	Elected Junior, October 2d, 1900; died March 1st, 1903.
Franklin, William Buel	Elected Member, April 1st, 1874; died March 8th, 1903.
Rives, Alfred L.	Elected Member, September 4th, 1872; died February 27th, 1903.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(February 11th to March 10th, 1903.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Eng. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des École Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
(46) *Scientific American*, New York City, 8c.
(47) *Mechanical Engineer*, Manchester, England.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.

LIST OF ARTICLES.

Bridge.

Pile Sinking by Means of a Hydraulic Jet at Moruya and Carrington Bridges, New South Wales.* Ernest Macartney De Burgh, M. Inst. C. E. (63) Vol. cl.

On Some Methods of Steel Bridge Erection.* William Sharpe, Assoc. M. Inst. C. E. (63) Vol. cl.

The Teesta Bridge.* William Robert Shaw, M. Inst. C. E. (63) Vol. cl.

The Approach to the Pennsylvania Railroad Bridge at Fifty-second Street, Philadelphia.* (14) Feb. 14.

The New Plans for the Manhattan Bridge Across the East River at New York City.* (13) Feb. 19. (14) Feb. 21.

Wooden Beams and Columns in Street Railway Bridge Construction.* H. B. Andrews. (17) Feb. 21.

The Nine-Mile Run Steel Arch Bridge at Pittsburg, Pa.* Willis Whited, Assoc. M. Am. Soc. C. E. (13) Feb. 26.

Viaduct Over the Viaur.* (12) Feb. 27.

The Blackwell's Island Bridge.* (14) Feb. 28.

The Construction of the Centers for the Luxemburg Arch Bridge.* (13) Mar. 5.

Résultats des Épreuves du Viaduc du Viaur. (38) Feb.

Déformation des Poutres Droites. Gaston Blot. (35) Serial beginning Feb.

Electrical.

Electrical Power at Sir B. Samuelson and Company's Ironworks, Middlesbrough.* Ernest D. Phillips. (22) Jan. 30.

Commutators.* (45) Feb.

Ship Lighting. Frank Broadbent. (26) Serial beginning Feb. 6.

The "Ward-Leonard" System of Electrically Operating Printing Machinery.* (26) Feb. 6.

Notes of Recent Electrical Design.* W. B. Esson, M. Inst. C. E. (Abstract of Paper read before the Inst. of Elec. Engrs.) (47) Serial beginning Feb. 7.

Electric Power Transmission at Arbroath.* (11) Feb. 13.

The Witton Works of the General Electric Company, Limited.* (26) Feb. 13.

Continuous-Current Motors for Machine Tools. F. O. Blackwell. (47) Feb. 14.

Electric Water Power at Manchester, N. H., Mills.* (27) Feb. 14.

Cable Construction for Telephone Lines; General Specifications. (27) Feb. 14 (Supplement).

Ampere-Hour Capacity of the Lead Storage Battery. A. L. Marsh. (27) Feb. 14.

Methods of Work Adopted in Constructing the Chicago Telephone Tunnels.* (13) Feb. 19.

The Joint Transmission of Differing Currents. Frederick Bedell. (19) Feb. 21.

Manufacture of Large Dynamos and Alternators.* Ernest Kilburn Scott. (Paper read before the Inst. of Elec. Engrs.) (47) Serial beginning Feb. 21.

The Mercury Arc. Charles P. Steinmetz. (27) Feb. 21.

Alternating *vs.* Direct Current, as Applied to the Iron and Steel Industry. C. H. Hines. (27) Feb. 21.

The Wiring of Buildings. O. L. Falconar. (Abstract of Paper read before the Inst. of Elec. Engrs.) (24) Feb. 23.

Electric Transmission Lines; Line Wire Materials and High Voltages. Alton D. Adams. (10) Mar.

Electrical Power in Iron and Steel Plants. Frank C. Perkins.* (62) Mar. 5.

British Westinghouse Works.* (27) Mar. 7.

Italian Recording Wattmeters.* (27) Mar. 7.

Tuned Wireless Telegraph Circuits. A. V. Thiessen. (Abstract of Paper in *Monthly Weather Review.*) (27) Mar. 7.

Elster and Geitel's Improved Form of Exner's Electroscope.* A. Frederick Collins. (27) Mar. 7.

The Use of High Tension Underground Conductors. Henry Floy. (27) Mar. 7.

Le Calcul de la Force Électromotrice Induite et du Facteur de Forme dans les Alternateurs. C. F. Guilbert. (36) Serial beginning Jan. 25.

Marine.

Torsion and Torsional Stresses in Propeller Shafts.* Hermann Frahm. (11) Feb. 6.

The Russian First Class Cruiser *Bogatyr*.* (11) Feb. 13.

A Brief History of Ocean Steamships. Lawrence Irwell. (19) Feb. 14.

Some Useful Data from Scotch Marine Engineering Practice. H. Wilkes. (13) Feb. 26.

Great Britain's Naval Supremacy.* Archibald S. Hurd. (10) Mar.

Mechanical.

On the Deformation of a Cast-Iron Pipe under External Vertical Pressure.* Joseph Francis, M. Inst. C. E. (63) Vol. cl.

An Optical Method of Determining the Deformations of a Rotating Fly-Wheel.* Samuel Henry Barraclough, Assoc. M. Inst. C. E. (63) Vol. cl.

Formulas Relating to Saturated Steam. Arthur William Brightmore, M. Inst. C. E. (63) Vol. cl.

Report of the Committee on Tabulating the Results of Steam-Engine and Boiler Trials; Inst. C. E.* (63) Vol. cl.

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* Illustrated.

Mechanical—(Continued).

The Paris Exhibition of Automobiles.* (11) Serial beginning Jan. 28.
Milling Machine Feeds. (12) Jan. 30.
Butler's Three-Cylinder Compound Gas Engine.* (47) Jan. 31.
"Petrogene" Air Gas to Replace Dear Coal Gas.* (66) Feb. 3.
The Crystal Palace Motor Car Show.* (12) Serial beginning Feb. 6.
The Fuel Value of Refuse. W. H. Booth. (26) Feb. 5.
High-Speed Cutting Steel. (47) Feb. 7.
Externally Fired Boilers.* William H. Fowler, M. Inst. C. E. (47) Feb. 7.
Engineering Works and Shop Lighting by the High-Pressure Gas System.* (66) Feb. 10.
High-Speed Tool Steel. (62) Feb. 12.
The Briquetting of Flue Dust, Fine Ore and Fuel.* (13) Feb. 12.
The Moore Hot Blast Stove. (20) Feb. 12.
Power Required to Drive Machine Tools; Locomotive Shops of the Buffalo, Rochester & Pittsburgh Railway at Du Bois, Pa.* (20) Feb. 12; (15) Feb. 18; (18) Feb. 14.
An Automatic Nut-Tapper and a Bolt-Threading Machine.* (22) Feb. 13.
Gas Engines for Electric Lighting. H. B. Graham. (Abstract of Paper read before the Inst. of Elec. Engrs.) (47) Feb. 14; (66) Feb. 8; (26) Feb. 6.
The Efficiency of Boiler Furnaces. C. E. Stromeyer. (47) Feb. 14.
The Airship System of M. Frederick L'Hoste.* T. Byard Collins. (19) Feb. 14.
The Balancing of Rolling Mill Engines.* George Service. (Paper read before the West of Scotland Iron and Steel Inst.) (47) Feb. 14.
A New Method of Testing Wire.* Arthur Falkenau. (62) Feb. 19.
The Relation of Boiler to Furnace. R. T. Strohm. (62) Feb. 19.
The Schwarz Drying and Mixing Machine for Manufacturing Lime-Sand Brick.* (13) Feb. 19.
The Valuation of Pig Iron for Foundry Purposes. Richard Moldenke. (Paper read before the New England Foundrymen's Assoc.) (20) Feb. 19.
The Use of Highly Superheated Steam. Prof. Ewing. (12) Feb. 20.
Large Horizontal Gas Engine.* (17) Feb. 21.
Anti-Friction Bearings.* Henry R. Lordly. (Assoc. of Civ. Engrs. of Cornell Univ.) (19) Feb. 21.
A New Double-Acting Tandem Internal-Combustion Engine.* (14) Feb. 21; (20) Feb. 26.
A Rapid Method for Determining Sulphur in Coal and Coke.* Carl Sundstrom. (24) Feb. 23.
German Progress in the Recovery of Cyanogen from Gas. (66) Serial beginning Feb. 24.
The Selection and Care of Leather Belting. D. B. Dixon. (62) Feb. 26.
Queen's Engineering Works, Bedford.* (11) Serial beginning Feb. 27.
The Steam Turbine. Geoffrey L. Parsons, A. M. I. C. E. (Abstract of Paper read before the Cleveland Inst. of Engrs.) (22) Feb. 27.
Machine Forging.* (22) Feb. 27.
Hydraulic Experiments on a Plunger Pump.* John Goodman. (Paper read before the Inst. of Mech. Engrs.) (11) Serial beginning Feb. 27; (47) Serial beginning Feb. 28; Abstract (22) Feb. 27.
Iron Furnace Boilers.* William H. Fowler. (47) Feb. 28.
The Modern Power Problem.* John Joseph Flather. (10) Serial beginning Mar.
Large Stop Valves for High Pressure Steam.* W. H. Booth. (64) Mar.
The Modern Plant; Practical Directions and Suggestions Concerning Its Design and Operation in Order to Secure the Best Results.* W. H. Wakeman. (41) Mar.
Smoke Abolition.* T. T. Parker. (64) Mar.
The Evolution of the Mechanical Stoker.* A. A. Cary. (Paper read before the New England Cotton Mfrs.' Assoc.) (64) Mar.
Valve Gear of the Buckeye Engine.* (64) Mar.
Transmission Rope Splicing.* Frederick S. Greene. (64) Mar.
Ammonia Concentration at Gas Works.* John S. Unger. (Paper read before Wisconsin Gas Assoc.) (24) Mar. 2.
A New Flexible Metallic Joint.* (13) Mar. 5.
Rotary Pressure Blowers. George C. Hicks, Jr. (Paper read before the Pittsburgh Foundrymen's Assoc.) (20) Mar. 5.
An Interesting Boiler House at Apponaug, R. I.* (14) Mar. 7.
A Second Year's Experience Distributing Artificial Gas Under High Pressure. Geo. F. Goodnow. (Paper read before the Wisconsin Gas Assoc.) (24) Mar. 9.
Note sur des Dispositifs de Sécurité à Appliquer aux Récipients de Vapeur à Convercle Amovible. Maurice Bellom. (43) 3e Trimestre, 1902.
Note sur la Théorie des Régulateurs des Machines à Vapeur. V. Dwelshauvers-Dery. (37) Jan.
Sur les Phénomènes de la Combustion dans les Moteurs Fixes à Alcool. M. Sorel. (37) Serial beginning Jan.
Sur Quelques Dispositions Récentes de Distributions par Soupapes.* M. Svilokossitch. (36) Serial beginning Jan. 25.
Gazogènes par Aspiration.* (34) Feb.
Rouleaux Compresseurs à Traction Électrique des Digues de Grosbois et Saint-Fargeau.* A. Dumas. (33) Feb. 7.
La Voiture Automobile en 1902.* (33) Serial beginning Feb. 21.

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* Illustrated.

Metallurgical.

Metallurgy in Its Relations to Engineering.* Sir William Roberts-Austen, Hon. M. Inst C. E. (63) Vol. cl.

The Valuation of Iron Ores for Blast Furnace Charges. (62) Feb. 12.

Classifying Steel Ingots, and the Influence of Chemical Composition on Their Solidity.* (20) Feb. 19.

The Stassano Electric Steel Furnace; an Italian Direct Reduction Process. Hans Goldschmidt. (Paper read before the Electrotechnische Gesellschaft.) (20) Feb. 19.

The Largest Malleable Casting Plant in Europe.* (20) Feb. 26.

The Electrolytic Refining of Silver and Gold.* Titus Ulke. (45) Mar.

Cyanidation at the Homestake Mine. C. W. Merrill. (16) Mar. 7.

État Actuel de la Préparation Mécanique des Minerais.* H. Lenicque. (32) Dec.

Nouveaux Procédés d'Extraction de l'Or.* H. de la Coux. (33) Serial beginning Feb. 7.

Military.

The Hotchkiss Ordnance Company, Limited.* (11) Serial beginning Feb. 20.

Mining.

Shaft-Sinking through Water-Bearing Strata.* (57) Jan. 30.

Electric Pumping Plant at Kaiserstuhl II Shaft, Dortmund, Germany; a Description of the Steam Plant and Electric Machinery.* Frank C. Perkins. (45) Feb.

Safety Lamps and Colliery Explosions; Facts in Regard to Failures of Lamps in Atmospheres Charged with Gas and Coal Dust.* James Ashworth. (From the *Canadian Min. Review.*) (45) Feb.

How to Pan Gold from Gravel. (13) Feb. 12.

The Genetic Classification of Ore-Bodies: A Proposal and a Discussion. (16) Feb. 14.

The Concentration of Ores by Oil.* Walter McDermott. (16) Serial beginning Feb. 14.

Deep Mining in the Transvaal. H. H. Webb. (16) Feb. 14.

"Ore Developed": A Definition.* Philip Argall. (16) Feb. 14.

Application of Electricity to Mining. Daniel Burns. (Paper read before the Glasgow Technical College Scientific Society.) (57) Serial beginning Feb. 20.

Missfires. E. H. Weiskopf. (16) Feb. 21.

Report on a Co-operative Chemical Analysis of a Copper Slag. Thorn Smith. (16) Feb. 21.

A Study in the Economical Arrangement of Compressed Air Haulage. Ernest Brackett. (16) Feb. 28.

Compressive Strength of Anthracite Coal (Coal Test Committee, Scranton Engrs.' Club.) (45) Mar.

The Head Frames of Shafts at Cripple Creek.* Alexander Forsyth. (16) Mar. 7.

Miscellaneous.

Reclamation of Drift-Sands in Cape Colony.* Charles Dimond Horatio Braine. (63) Vol. cl.

The Greenwich Footway Tunnel.* William Charles Copperthwaite, M. Inst. C. E. (63) Vol. cl.

Metric Measurement. Robert H. Smith. (26) Feb. 13.

Asphalt Refining; Methods Employed in the Tar Springs Asphalt Co.'s Refinery, near Comanche, Ind. T.* W. R. Crane. (45) Mar.

Municipal.

A Steam Roller of Wide Adaptability.* (14) Feb. 14; (13) Feb. 12.

Report of the Park Commission to the Senate Committee on the District of Columbia: A Review.* Arthur A. Shurtleff. (14) Feb. 14.

Macadam Roads and Specifications. Ernest McCullough. (13) Feb. 26.

Parkways and Boulevards for Philadelphia, Pa.* William E. Bray. (60) Mar.

Pavages des Villes des États-Unis d'Amérique: Rapport de Mission.* V. Vaillant. (30) Feb.

Le Nouveau Tunnel sous la Tamise, à Londres entre Greenwich et Millwall.* Richard Essayie. (33) Feb. 21.

Railroad.

Locomotive Fire-Box Stays.* Francis William Webb, Vice-Pres. Inst. C. E. (63) Vol. cl.

Tables of Formulas for Points and Crossings.* Evelyn Henry Young, Assoc. M. Inst. C. E. (63) vol. cl.

Federated Malay States Railways, Perak and Province Wellesley.* Charles Rastrick Hanson, M. Inst. C. E. (63) vol. cl.

Tunnel Construction under Water.* Howard A. Carson. (1) Dec.

Some Brake-Tests and Deductions Therefrom.* J. D. Keiley. (42) Jan.

Railroad Car Braking.* R. A. Parke. (42) Jan.

Cast Iron Wheels to Meet To-day's Requirements. F. W. Sargent and others. (65) Jan. 16.

Valtellina High-Tension Three-Phase Railway.* (12) Serial beginning Jan. 30.

Three-Cylinder Ten-Coupled Tank Engine; Great Eastern Railway. (21) Feb.

Fog Signalling. (21) Serial beginning Feb.

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* Illustrated.

Railroad—(Continued).

Twenty-five Years of Locomotive Development. (39) Feb.
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Development of Railway Signaling in the Last Twenty-five Years. (39) Feb.
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Suburban Locomotive, Great Eastern Railway.* (12) Feb. 6; (15) Feb. 27.
Midland Railway Three-Cylinder Compound Passenger Locomotives.* (11) Feb. 6.
The Miller System of Automatic Railway Signalling.* (11) Feb. 18; (26) Feb. 18; (12) Feb. 18.
The Friction Draft-Gear Problem. R. A. Parke. (Extracts from Paper read before the New England R. R. Club.) (15) Feb. 18.
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INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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AN INVESTIGATION OF THE PROPERTIES OF BRICK, UNDER DIFFERENT PHYSICAL CONDITIONS.

By Sherman M. Turrill, Assoc. Am. Soc. C. E.

To be Presented April 15th, 1903.

This article is based upon tests conducted in the Civil Engineering Laboratories at Cornell University, during the early part of the year 1901, by the writer, assisted by Professor C. L. Crandall, with suggestions from Professor G. S. Williams.

The methods of procedure, the results of the tests, and the outline of the conclusions are given; and the writer hopes that a complete discussion of the conclusions and a comparison of the work with preceding work in the same line may be brought out.

General Description of the Investigation.

All the brick used in this investigation were common building brick, made at Horseheads, New York, by the Horseheads Brick Company, and were of the usual size (8 x 4 x 2 ins.), but varied, more or less, from these dimensions, being a little less than 4 ins. wide and a little more than 2 ins. thick. In their manufacture a mixture of clay and shale was used, and they were made by the stiff-mud process, under modern methods.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

The tests conducted were as follows:

- Compressive tests of whole brick on end, edge, and flat, and of brick cubes;
- Tension tests;
- Bending or transverse tests;
- Shearing and torsion tests.

The conditions were:

- Natural brick;
- Brick filled with water;
- Reheated brick.

By "natural brick" is meant brick in its natural condition when placed on the market. By "brick filled with water" is meant brick placed under water for a sufficient period to be thoroughly saturated prior to testing, this condition existing until the test was completed. By "reheated brick" is meant brick which has been subjected to a high temperature after its entrance into the commercial world.

In making the tests for compression, the bearings were ground, and, in addition, plaster of Paris and building paper were used. The cubes were, in general, 2 ins. square, two cubes being sawed from one brick. In the tension and torsion tests, the surfaces were not ground, but building paper was used for a bearing. In the shearing and bending tests, the surfaces were not ground, nor was plaster of Paris or paper used on the bearings.

Purpose of the Investigation.

The object in carrying out these tests was to ascertain the weak points of a brick, and, as brick are subjected to compression, tension, bending, shear and torsion, to a greater or less degree, it seemed best to test them under all these conditions and compare the results.

In testing brick under the three conditions, natural, filled with water, and reheated, the writer had in mind brick used in dry places, brick used in wet places, and brick which were to be used again after having passed through a great fire.

In dealing with brick continually under water, without taking into consideration the effect of freezing, one might question their strength as compared with natural brick. In that part of the investigation, special pains were taken to see that the brick were placed under water for at least 1½ months, so that they should be, as nearly as possible, in the actual condition of brick continually under water.

In the case of reheated brick, as, for example, those which have passed through a great conflagration, there is a question as to the advisability of using such brick, and that was one of the reasons for including this condition in the investigation. In order to bring about this condition, as well as to find the weight of the brick when void of moisture, an oven was built, Fig. 1, Plate XXII, in which the specimens were heated. After the brick were cooled, each one was sounded with a hammer. If it was shaky, it was thrown away; but if it had the ring of a sound brick, it was saved and tested. The question then arose: "Is the hammer test reliable as to the soundness of reheated brick?" The results of these tests show that it is, and that by testing reheated brick with a hammer, about 12% of them were found to be shaky.

Properties of the Brick Tested.

Analysis.—The following is an analysis of the brick tested:

Silica	(SiO_2)	64.61	per cent.
Alumina	(Al_2O_3)	20.10	"
Iron oxide	(Fe_2O_3)	6.30	"
Calcium oxide	(CaO)	6.21	"
Magnesia	(MgO)	2.50	"
Sulphur trioxide	(SO_3)	trace	"
Loss on ignition		0.08	"
Total		99.80	"
Specific Gravity		2.66	

Absorption of Water.—In determining the quantity of water absorbed, 500 brick of such varying hardnesses as would represent all grades found in building brick, were first selected. These brick were then placed in the oven shown in Fig. 1. Plate XXII, and were subjected to a high degree of heat, night and day, for one week. At the end of that time it was found that the moisture in the brick had entirely disappeared. Each brick was then taken out of the oven separately and weighed while it still contained its maximum heat, the fire being kept going until every brick was weighed. The weight of each of the 500 brick in the dry state was ascertained by this means.

These 500 brick were next placed under water for about 2 weeks, until they had absorbed all the moisture they could. Each brick was

PLATE XXII.
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TURRILL ON PHYSICAL PROPERTIES
OF BRICK.

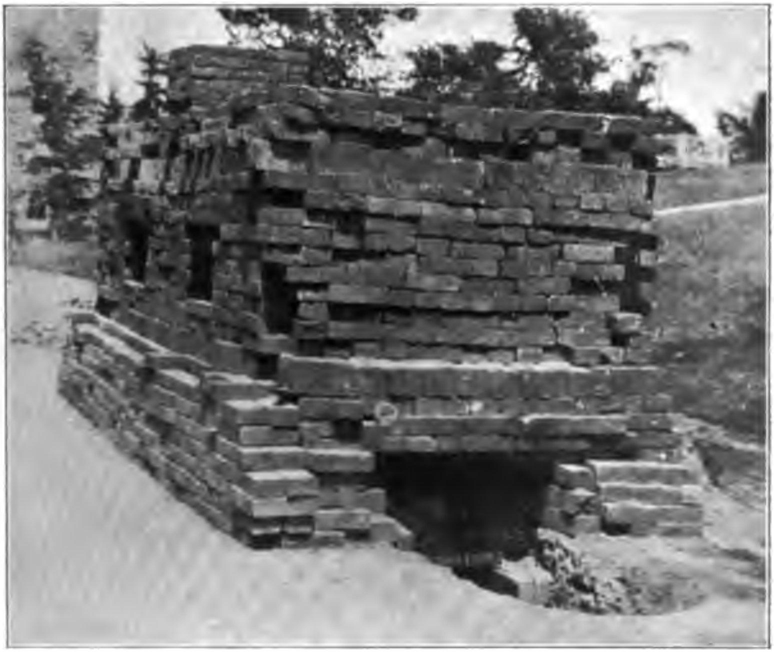


Fig. 1.—Brick Oven, where Moisture in Brick Was Driven Off.

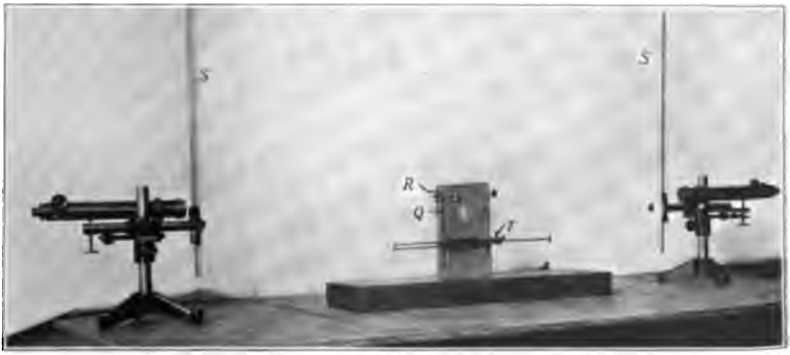


Fig. 2.—Apparatus Used in Determining the Elastic Properties of Brick.

R = Rocker Bearing.
S = Scale.
Q = Rocker Lever.
T = Clamp.

then taken out separately and weighed, and thus the weight of each brick saturated with moisture was determined. Before weighing, the surplus water on the surface was removed by means of blotters. This gave the two weights necessary for determining the quantity of moisture absorbed.

Table No. 1 shows the range of absorption found, and is a good guide as to the absorption in common building brick. In this table it is seen that brick No. 63 has the lowest absorption, being only 147.4 gr., which is only 7% of its weight in the dry state; while the highest absorbed 490.7 gr., which is 14.19% of its dry weight. The average results from the 500 brick are also recorded in Table No. 1, and show a larger percentage of absorption than is generally allowed in specifications for common building brick. In specifications, in determining the percentage of absorption to be permitted, the weights of the natural brick and bricks filled with water are generally used. This method would tend to decrease the percentage of absorption, as recorded in Table No. 1, and bring it very close to that specified generally.

TABLE No. 1.—ABSORPTION OF WATER IN BRICK.

Brick No.	Weight, in grams, before immersion.	Weight, in grams, after immersion.	Weight, in grams, of water absorbed.	Percentage of water absorbed.	Remarks.
42	1 993.0	2 193.6	200.6	10.07	
63	2 105.8	2 249.7	147.4	7.00	Very hard. Absorbed less water than any one of the 500 brick.
108	2 128.5	2 449.1	320.6	15.06	
109	2 015.8	2 506.5	490.7	24.34	Very soft. Absorbed more water than any one of the 500 brick.
173	1 995.5	2 222.8	227.3	11.39	
190	2 021.2	2 341.8	321.6	15.91	
217	1 997.0	2 315.7	318.7	15.95	
221	2 012.4	2 211.6	199.2	9.89	
225	2 087.0	2 369.4	282.4	13.53	
296	2 135.5	2 502.3	366.8	14.62	
365	2 129.1	2 462.6	333.5	15.66	
400	2 026.5	2 347.8	321.3	15.85	
Averages	2 053.9	2 347.7	294.2	14.19	
Average results from 500 specimens tested	2 030.52	2 351.39	320.87	15.80	

In constructing the oven, a hole, for an ash pit, was dug in the ground, the grate was placed on a level with the ground, and around this was built the oven. No bonding material was used in the casing of the oven, the bricks being piled so as to break joints properly. In places where beams were required, wrought-iron pipes were used, and the brick placed on them. In order to prevent leakage of heat, as much as possible, the larger openings in the joints were filled with sand, and the roof was covered with a thick layer of the same substance.

METHOD AND APPARATUS USED IN DETERMINING THE ELASTIC PROPERTIES.

All the brick used in determining the elastic properties were tested endwise. The initial load was 100 lbs., and when this load was applied, the initial reading was taken. A total load of 500 lbs. was then applied and a second reading taken. The load was then removed until a total of 100 lbs. was again obtained and a third reading taken. A pressure of 1 000 lbs. was applied and a fourth reading taken. The loading was again reduced to 100 lbs. and a fifth reading taken. This method of loading, unloading and reading was followed until it became evident that it would no longer be safe to allow the apparatus to remain attached to the brick. This part of the apparatus was then taken off, and the brick was tested for compression, endwise.

The foregoing method was followed with each of the bricks, and for each four curves were plotted as guides in determining its elastic properties. Two of the curves were plotted from readings taken from one edge, and the other two from the opposite edge of the brick. The plotting of the values on each side, computed from the differences of readings between the initial and the successive 100-lb. readings, gives the curve of permanent set. The two curves, one on each side, plotted from the values derived from the differences of readings between the initial loading and those of 500, 1 000, 1 500 lbs., etc., respectively, give the curve of distortion under the respective loadings. The average of the curves of permanent set for each brick was ascertained by taking the arithmetic mean—that is, the sum of the two values for the corresponding loading divided by two. The same method was followed in ascertaining the averages of the curves of distortion, thus making two average curves for each brick.

The apparatus used is shown in Fig. 2, Plate XXII, and consists essentially of two sets of parts, those not attached to the brick and those attached to the brick. In the former, for each side of the brick, there is a standard containing a telescope with vertical and horizontal slow-motion screws, and a scale, *S*, graduated to centimeters. The latter consists of two rocker-levers, *Q*, rocker-bearings, *R*, with a mirror at one end of each, one of each for each side of the brick, and a clamp, *T*.

Where *R* and the lower end of *Q* would naturally bear against the brick, a small brass plate, in each place, was cemented to the brick, giving a brass bearing for these points. The details at *R* and the lower end of *Q* are shown in Fig. 1.

Now, as pressure is applied on the end of the brick, in the direction of the arrow, *A*, as shown in Fig. 1, the inside corner of *R* moves down, revolving about the edge in the groove of *Q* as a center. By this means, the mirror at the end of *R* moves through the same angle as *R*, thus giving different readings on the scale, *S*. The clamp, *T*, was used to hold *Q* and *R* in position.

When a total load of 100 lbs. was applied, the investigator looked through the telescope at the mirror and read the scale, in centimeters. On applying a heavier load on the brick, the mirror revolved, and a reading higher up the scale was obtained. The question then resolved itself into this form: How to find, from the differences of readings, the distortions under the respective loadings? Being able to find the differences of readings on the scale, then, by placing the scale, *S*, at a definite distance from the mirror, a constant was determined, which, when divided into the differences of scale readings, would give the distortions per unit of length for corresponding differences of loadings. This quantity is called the constant of the machine.

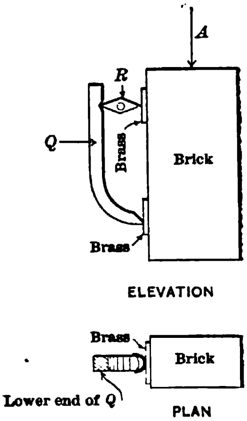


FIG. 1.

The determination of the constant for the apparatus is worked out as follows:

Length of $Q = 15$ cm.

Horizontal distance between bearings of $R = 0.44958$ cm.

Let the difference of readings (which means the difference between the initial reading and any other reading taken thereafter) be denoted by a; the distance from the mirror to the scale is denoted by z. After a little computing, it was found that, with a constant of 6 000, a convenient value for z was obtained.

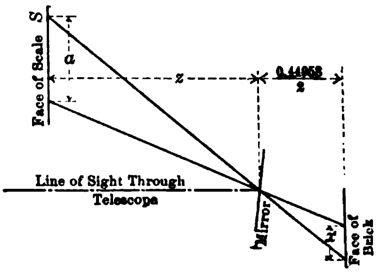


FIG. 2.

Let the total amount of distortion be denoted by x, then the distortion per unit of length is $= \frac{x}{15}$.

In the similar triangles of Fig. 2:

$$a : x = z : \frac{0.44958}{2}$$

Therefore $$x = \frac{\frac{0.44958\,a}{2}}{z} = \frac{a}{\frac{2z}{0.44958}}$$

Therefore $$x = \frac{\text{Difference of scale reading.}}{\frac{2 \text{ distance of scale from mirror.}}{0.44958}}$$

Hence $$\frac{x}{15} = \frac{\text{Difference of scale reading.}}{\frac{15 \times 2 \text{ distance of scale from mirror.}}{0.44958}}$$

= distortion per unit of length; and is applicable to any system of units.

Let $$6\,000 = \frac{15 \times 2 \text{ distance of scale from mirror.}}{0.44958}$$

Therefore z, distance of scale from mirror, $= \frac{6\,000 \times 0.44958}{2 \times 15}$

$$= 89.916 \text{ cm.} \doteq 34.4 \text{ ins.} = 2.95 \text{ ft.}$$

Therefore $$\frac{x}{15} = \frac{\text{Difference of scale reading.}}{6\,000}$$

Then, by placing the scale, S, 2.95 ft. from the mirror, the distortion per unit of length $\left(\frac{x}{15}\right)$ was obtained at a glance.

By this method the quantities used in plotting the elastic curves were obtained.

COMPRESSIVE TESTS OF BRICK.

This set was tested in the Riehlé, 400 000-lb. testing machine, and consists of brick on edge, on end, and flat, and 2-in. cubes, for natural, filled-with-water, and reheated brick. The brick tested on end were first tested for elastic properties, and, after the mirror micrometers had been removed, were tested for compression.

The photographs on Plates XXIV, XXV and XXVI show that in all cases the fractures are, in general, double-coned in outline, and that the apices of the cones meet in the middle. It will also be seen that the angle of the fracture with the bed-plane changes somewhat according to the way the bricks were tested, and varies more or less from 60 degrees.

In testing any material under compression it is claimed that a more accurate test is obtained by using cubes instead of rectangular blocks, the theory being that if tested on the flat a considerable percentage of the stress necessary for crushing is used up in friction, which takes place when the outside portion of the brick is pushed away to give room for the interior to crush, thus causing a greater stress than is necessary for crushing. In the case of testing on edge and on end it is advanced that bending, as in a column, is introduced to some extent. In the case of the cube there is no loss of stress due to friction on the bed-plate or head-block, and no tendency to bending, as in a column; and these, alone, are good reasons for selecting the cube as the ideal form of test piece.

By comparing the averages shown in Tables Nos. 2 to 8, it will be seen that in every case brick on the flat are the strongest, those on edge next to the strongest, those on end next to the weakest, while the cubes are the weakest. It will also be seen that in all cases reheated brick are the strongest, while brick filled with water are the weakest in the end and edge tests, and that natural brick are weakest in the flat and cube tests. Taking the natural cube as a standard test piece, the percentages of increase have been computed as follows:

Cube of brick; natural	1.0
Cube of brick; filled with water	2.2
Cube of brick; reheated	4.4
Natural brick; on end	15.2
Natural brick; on edge	27.1
Natural brick; flat	79.3
Brick filled with water; on end	4.1
Brick filled with water; on edge	22.0
Brick filled with water; flat	104.8
Reheated brick; on end	28.9
Reheated brick; on edge	49.3
Reheated brick; flat	121.7

TABLE No. 2.—Compressive Tests of Brick on End, for Natural, Filled-with-Water, and Reheated Brick.

Numbers.			Area of section, in square inches.			Ultimate load, in pounds per square inch.			Equivalent ultimate load per unit of height, in pounds per square inch.		
Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.
97	1	14	8.53	8.66	8.89	3 763	2 092	3 063	30 102	17 391	24 699
98	2	25	8.91	8.77	8.70	1 234	3 198	2 169	9 952	15 945	17 348
99	3	26	8.54	8.91	8.89	2 742	1 603	2 717	22 536	13 120	21 990
100	4	53	8.70	8.65	8.77	2 826	2 281	2 509	22 698	18 393	20 229
101	5	73	8.65	8.72	8.84	2 952	1 977	3 446	23 898	16 004	28 000
102	6	91	8.70	8.53	8.77	2 783	3 153	1 908	22 085	24 436	15 388
103	7	94	8.72	8.58	8.96	1 663	2 539	2 918	18 357	20 074	23 711
104	8	100	8.84	8.84	8.51	2 602	2 553	2 343	21 063	20 825	18 962
105	9	104	8.15	8.86	8.67	2 101	2 280	1 737	16 874	19 036	13 630
106	10	171	8.53	8.72	8.72	3 339	2 523	2 905	23 802	21 527	22 879
107	11	176	8.72	8.91	8.30	2 606	1 829	3 336	21 498	15 059	31 051
108	12	185	8.22	8.54	8.58	2 976	1 802	4 896	23 808	14 865	39 169
Averages........			8.60	8.72	8.72	2 628	2 320	2 871	20 986	18 889	23 088

TABLE No. 3.—Compressive Tests of Brick on Edge, for Natural, Filled-with-Water, and Reheated Brick.

Numbers.			Area of section, in square inches.			Ultimate load, in pounds per square inch.			Equivalent ultimate load per unit of height, in pounds per square inch.		
Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.
109	13	194	19.30	17.45	18.35	2 187	2 890	3 521	8 146	10 580	13 427
110	14	283	17.96	18.93	18.00	3 099	2 226	4 278	11 711	8 348	13 984
111	15	285	18.18	18.34	18.21	3 021	2 284	2 550	11 610	8 685	9 404
112	16	412	18.32	18.28	18.35	3 199	3 165	2 722	12 096	11 969	10 463
113	17	416	17.96	18.68	18.14	2 878	2 591	3 438	10 614	9 728	13 215
114	18	426	18.39	18.72	18.28	2 055	2 445	3 258	7 771	9 245	12 098
115	19	430	18.61	18.14	17.87	3 050	2 567	2 502	11 628	10 507	9 617
116	20	459	18.03	18.72	18.28	2 621	2 291	3 605	9 829	8 590	13 405
117	21	465	18.03	18.00	18.39	2 949	2 707	3 931	11 150	10 150	14 864
118	22	467	17.77	18.75	18.39	1 897	2 720	4 043	7 290	8 840	15 540
119	23	468	17.75	18.00	18.46	3 913	4 104	2 986	14 674	15 007	11 479
120	24	479	18.21	18.57	19.19	3 164	2 623	3 087	14 459	9 919	11 867
Averages............			18.21	18.38	18.24	2 832	2 717	3 326	10 748	10 122	12 447

TABLE No. 4.—Compressive Tests of Brick on Flat, for Natural, Filled-with-Water, and Reheated Brick.

Numbers.			Area of section, in square inches.			Ultimate load, in pounds per square inch.			Equivalent ultimate load per unit of height, in pounds per square inch.		
Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.
121	25	128	31.23	30.99	31.37	4 183	5 893	5 256	8 758	12 707	11 662
122	26	160	31.35	31.35	29.77	4 310	4 783	5 783	9 294	10 049	12 651
123	27	161	31.35	31.23	31.11	5 463	4 923	5 831	12 122	10 462	12 572
124	28	181	31.48	31.35	31.11	2 791	4 527	5 807	6 104	8 771	11 775
125	29	189	31.38	31.36	31.36	3 539	3 359	3 541	7 851	6 925	7 745
126	30	279	32.87	31.23	31.74	2 665	5 613	3 862	5 650	11 402	8 327
127	31	346	31.23	31.48	31.62	4 525	4 583	4 419	9 898	10 024	9 804
128	32	411	31.48	31.10	32.12	3 941	5 308	3 975	8 745	11 269	9 069
129	33	431	31.97	31.95	30.98	3 623	4 005	4 482	8 039	8 510	10 084
130	34	432	30.35	31.73	31.86	3 999	3 623	5 792	8 625	8 039	12 670
131	35	442	31.73	31.36	31.24	4 272	5 039	6 520	9 078	11 021	14 059
132	36	487	31.11	31.21	31.48	4 625	3 097	4 500	9 973	6 774	9 563
Averages			31.45	31.36	31.31	3 995	4 562	4 980	8 678	9 663	10 832

TABLE No. 5.—Compressive Tests of Natural Brick.

Numbers.			Area of Section, in square inches.			Ultimate load, in pounds per square inch.			Equivalent ultimate load per unit of height, in pounds per square inch.		
End.	Edge.	Flat.	End.	Edge.	Flat.	End.	Edge.	Flat.	End.	Edge.	Flat.
97	109	121	8.53	19.30	31.23	3 763	2 137	4 183	30 102	8 146	8 758
98	110	122	8.91	17.96	31.35	1 234	3 099	4 310	9 952	11 711	9 294
99	111	123	8.54	18.18	31.35	2 742	3 021	5 463	22 536	11 610	12 122
100	112	124	8.70	18.32	31.48	2 826	3 199	2 791	22 698	12 096	6 104
101	113	125	8.65	17.96	31.38	2 952	2 878	3 539	23 893	10 614	7 851
102	114	126	8.70	18.39	32.87	2 733	2 055	2 665	22 085	7 771	5 650
103	115	127	8.72	18.61	31.23	1 663	3 050	4 525	13 357	11 628	9 898
104	116	128	8.84	18.08	31.48	2 602	2 621	3 941	21 063	9 829	8 745
105	117	129	8.15	18.02	31.97	2 101	2 949	3 623	16 874	11 150	8 039
106	118	130	8.53	17.77	30.35	3 339	1 897	3 999	23 802	7 290	8 625
107	119	131	8.72	17.75	31.73	2 606	3 913	4 272	21 498	14 674	9 078
108	120	132	8.23	18.21	31.11	2 976	3 164	4 625	23 808	12 459	9 973
Averages..........			8.60	18.21	31.45	2 628	2 832	3 995	20 986	10 748	8 678

TABLE No. 6.—COMPRESSIVE TESTS OF BRICK FILLED WITH WATER.

NUMBERS.			AREA OF SECTION, IN SQUARE INCHES.			ULTIMATE LOAD, IN POUNDS PER SQUARE INCH.			EQUIVALENT ULTIMATE LOAD PER UNIT OF HEIGHT, IN POUNDS PER SQUARE INCH.		
End.	Edge.	Flat.	End.	Edge.	Flat.	End.	Edge.	Flat.	End.	Edge.	Flat.
1	13	25	8.60	17.45	30.99	2 092	2 880	5 893	17 391	10 530	12 707
2	14	26	8.77	18.93	31.35	3 198	2 226	4 783	25 945	8 348	10 049
3	15	27	8.91	18.34	31.23	1 603	2 284	4 923	13 120	8 685	10 463
4	16	28	8.65	18.28	31.35	2 281	3 165	4 527	18 893	11 969	8 771
5	17	29	8.72	18.68	31.36	1 977	2 594	3 859	16 004	9 728	6 925
6	18	30	8.53	18.72	31.23	3 153	2 445	5 613	24 436	9 245	11 403
7	19	31	8.58	18.14	31.48	2 539	2 567	4 583	20 074	10 507	10 024
8	20	32	8.84	18.72	31.10	2 553	2 291	5 305	20 825	8 590	11 369
9	21	33	8.86	18.00	31.95	2 289	2 707	4 005	19 028	10 150	8 510
10	22	34	8.72	18.75	31.73	2 593	2 720	3 623	21 527	8 840	8 099
11	23	35	8.91	18.00	31.36	1 829	4 104	5 089	15 059	15 007	11 021
12	24	36	8.54	18.57	31.21	1 802	2 623	3 097	14 865	9 919	6 774
Averages.......			8.78	18.38	31.36	2 320	2 717	4 562	18 889	10 122	9 663

TABLE No. 7.—COMPRESSIVE TESTS OF REHEATED BRICK.

NUMBERS.			AREA OF SECTION, IN SQUARE INCHES.			ULTIMATE LOAD, IN POUNDS PER SQUARE INCH.			EQUIVALENT ULTIMATE LOAD PER UNIT OF HEIGHT, IN POUNDS PER SQUARE INCH.		
End.	Edge.	Flat.	End.	Edge.	Flat.	End.	Edge.	Flat.	End.	Edge.	Flat.
14	194	128	8.89	18.35	31.37	3 068	3 521	5 256	24 699	13 427	11 662
25	233	160	8.70	18.00	29.77	2 169	4 278	5 783	17 348	13 984	12 651
26	285	161	8.89	18.21	31.11	2 717	2 550	5 831	21 990	9 404	12 572
53	412	181	8.77	18.35	31.11	2 509	2 722	5 307	20 229	10 462	11 775
73	416	189	8.84	18.14	31.36	3 446	3 438	3 541	28 000	13 215	7 745
91	426	279	8.77	18.28	31.74	1 908	3 253	3 862	15 383	12 098	8 327
94	430	346	8.96	17.87	31.62	2 918	2 502	4 419	23 711	9 617	9 804
100	459	411	8.51	18.28	32.12	2 343	3 605	3 975	18 962	13 405	9 069
104	465	431	8.67	18.39	30.98	1 737	3 931	4 482	13 630	14 864	10 084
171	467	432	8.72	18.39	31.86	2 905	4 043	5 792	22 879	15 540	12 670
176	468	442	8.30	18.46	31.24	3 836	2 986	6 520	31 051	11 479	14 059
185	479	487	8.58	19.19	31.48	4 896	3 087	4 500	39 169	11 867	9 563
Averages..........			8.72	18.24	31.31	2 871	3 326	4 939	23 068	12 447	10 882

TABLE No. 8.—COMPRESSIVE TESTS OF TWO-INCH CUBES FOR NATURAL, FILLED-WITH-WATER, AND REHEATED BRICK CUBES.

NUMBERS.			AREA OF SECTION, IN SQUARE INCHES.			ULTIMATE LOAD, IN POUNDS PER SQUARE INCH.			EQUIVALENT ULTIMATE LOAD PER UNIT OF HEIGHT, IN POUNDS PER SQUARE INCH.		
Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.
*1	*13	95*a*	4.00	4.13	3.88	1 750	1 467	2 328	3 500	2 934	4 556
2	14	95*b*	4.13	4.00	4.13	3 965	3 500	2 179	7 970	7 000	4 358
3	15	152*a*	4.00	4.19	3.94	2 830	2 549	2 208	7 429	6 691	4 278
4	16	152*b*	4.13	4.06	3.94	2 864	2 628	2 292	5 728	5 256	4 584
5	17	228*a*	4.13	4.19	4.00	3 406	3 819	2 540	8 933	7 757	5 080
	18*a*	....	....	4.13	....	....	1 640	....	....	3 331	....
6	18*b*	228*b*	4.19	4.06	4.06	1 715	1 344	2 709	4 502	3 688	5 518
7	19	347*a*	4.00	3.94	4.06	1 351	1 294	2 345	2 744	2 588	4 690
8	20	347*b*	4.06	4.13	4.06	1 106	1 094	2 841	2 247	2 188	5 682
9	21	421*a*	4.33	4.13	4.00	1 575	1 398	2 106	3 150	2 796	4 278
10	22	421*b*	4.32	4.13	3.91	2 609	2 838	2 142	6 849	5 753	4 284
11	23	447*a*	4.19	4.13	3.88	1 515	1 617	1 885	3 159	3 234	3 716
12	24	447*b*	4.00	4.13	3.94	2 035	3 234	2 338	4 070	3 489	4 580
Averages........			4.13	4.10	3.99	2 228	2 273	2 326	5 023	4 878	4 688

* Nos. 1 and 13 were taken from the same brick, Nos. 2 and 14 from another brick, and the same order was followed for all the natural, and filled-with-water cubes, excepting in the cases of Nos. 6, 18*a* and 18*b*, in which cases three cubes were cut out of one brick.

A large hole was found in No. 18*a*, and though its test is recorded in this table, it is not included in the averages. No. 18*b* was cut from the same brick, and its test is included in the averages.

Taking the filled-with-water cube and the reheated cube as standards, the following percentages of increase have been computed: 2.1, 17.3, 100.7; 23.4, 43.0, 111.9 for end, edge, and flat, of filled-with-water and reheated brick, respectively. In Tables Nos. 2 to 8 the equivalent ultimate load per unit of height is given in pounds per square inch. This was obtained by multiplying the ultimate load, in pounds per square inch, by the height of the test piece. The object of ascertaining this was to see if some relation could be shown between the strength of a standard test piece (for example, a cube) and any other test piece, when the ratios of the areas to the heights are given.

In regard to the elastic properties, the averages of the results are shown by means of elastic curves, as seen in Figs. 3 and 4 and Plate XXIII. There are two methods of averaging these curves, the results of one being shown in Figs. 3 and 4, and the other on Plate XXIII, and

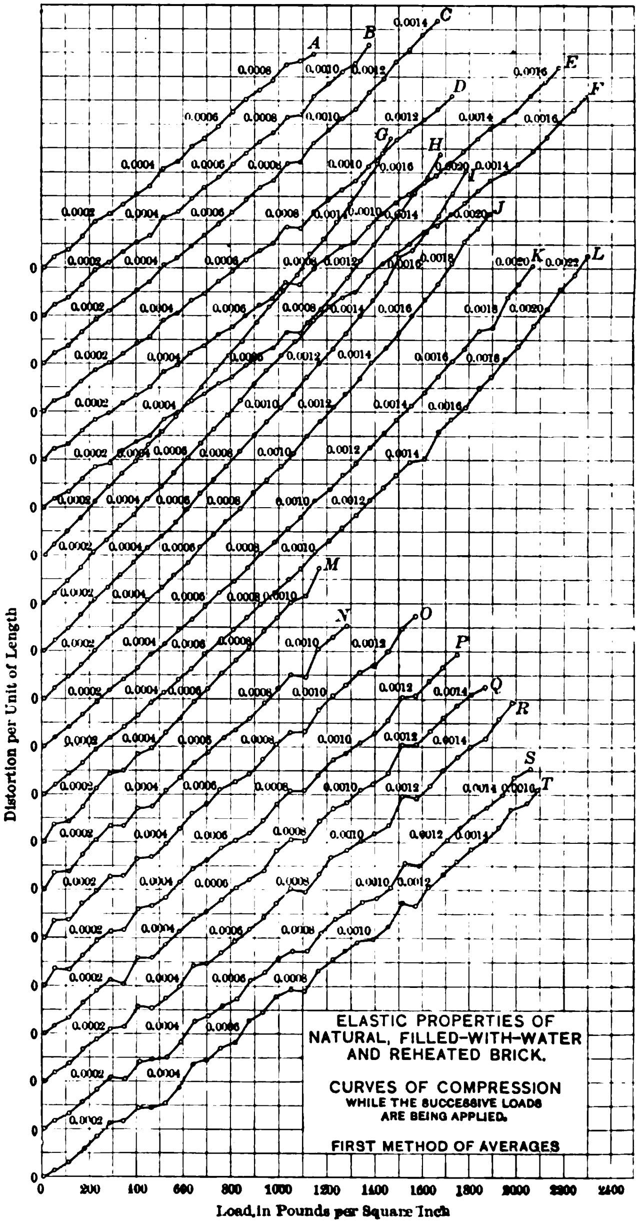
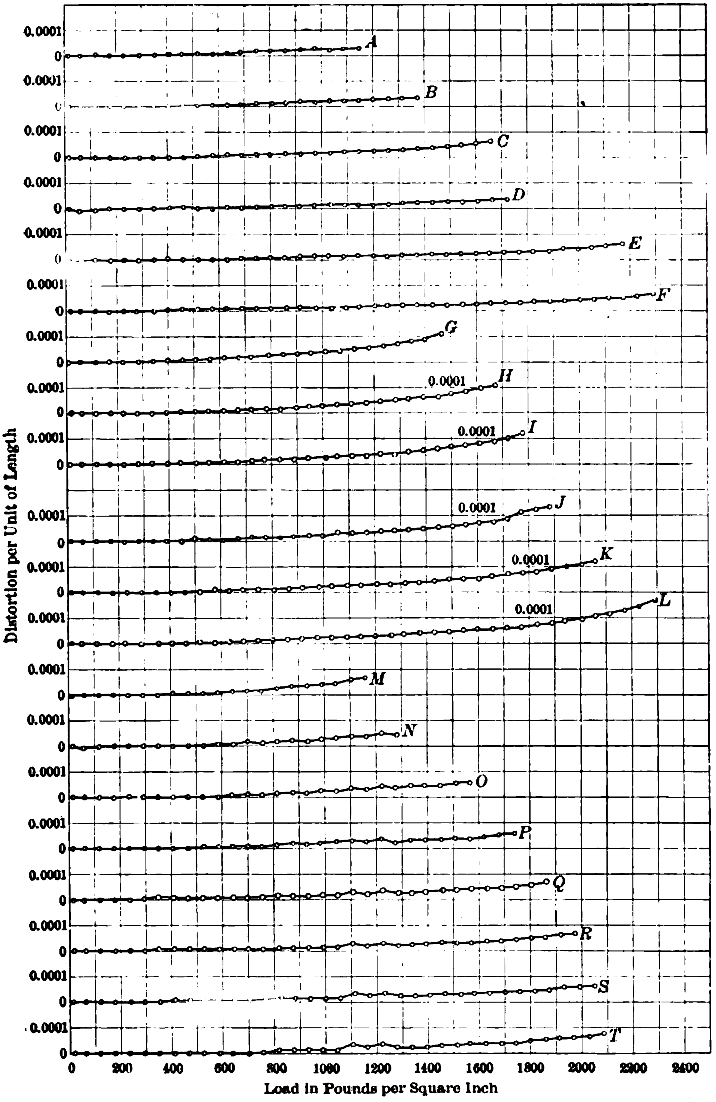

A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
ELASTIC PROPERTIES OF
NATURAL, FILLED-WITH-WATER
AND REHEATED BRICK.
CURVES OF COMPRESSION
WHILE THE SUCCESSIVE LOADS
ARE BEING APPLIED.
FIRST METHOD OF AVERAGES
Distortion per Unit of Length
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
Load, in Pounds per Square Inch

FIG. 3.



ELASTIC PROPERTIES OF
NATURAL, FILLED-WITH-WATER, AND REHEATED BRICK.

CURVES OF PERMANENT SET
AFTER THE SUCCESSIVE LOADS HAVE BEEN APPLIED AND THEN REMOVED

FIRST METHOD OF AVERAGES

FIG. 4.

each method is divided into two sets, *viz.*, curves of compression and curves of permanent set, for natural, filled-with-water, and reheated brick. In the former set the curves are plotted from values obtained while the successive total loads of 100, 500, 1 000, 1 500 lbs., etc., were being applied, and in the latter case while the successive 100-lb. loadings were being applied. In these curves, the initial loading was taken as 100 lbs., which was 11 lbs. per square inch, more or less, instead of zero. The object in doing this was to be sure that the head-block was not removed from the test piece after it was once placed, thus securing the same bearing, which would not have always been the case had zero been used for the initial loading.

All the elastic curves, marked *M* to *T*, *G* to *L* and *A* to F, inclusive, are averages of natural, filled-with-water, and reheated brick, respectively. The method of averaging, in the first set, Figs. 3 and 4, taking the natural brick as an example, is as follows:

The total loadings reached by the several bricks, before the rocker bearing and rocker lever were removed, were as follows:

Brick No. 97	18 000 lbs.
" " 101	
" " 104	
" " 106	
" " 108	17 500 "
" " 107	17 000 "
" " 102	16 000 "
" " 99	15 000 "
" " 100	
" " 103	14 500 "
" " 105	11 000 "
" " 98	10 000 "

Bricks Nos. 97, 101, 104 and 106 were averaged together up to 18 000 lbs. loading, making an average of four bricks, as shown in Curve *T*. Brick No. 108, together with Bricks Nos. 97, 101, 104 and 106, were averaged up to 17 500 lbs., making an average of five bricks for 17 500 lbs., as shown in Curve *S*. Brick No. 107, together with Bricks Nos. 97, 101, 104, 106 and 108, were averaged up to 17 000 lbs., making an average of six bricks, as shown in Curve *R*. Brick No. 102, together with Bricks Nos. 97, 101, 104, 106, 107 and 108, were averaged

PLATE XXIII.
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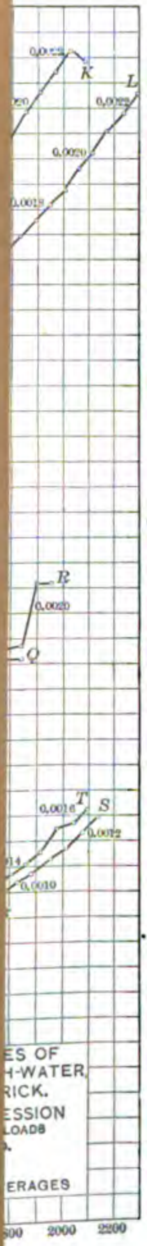
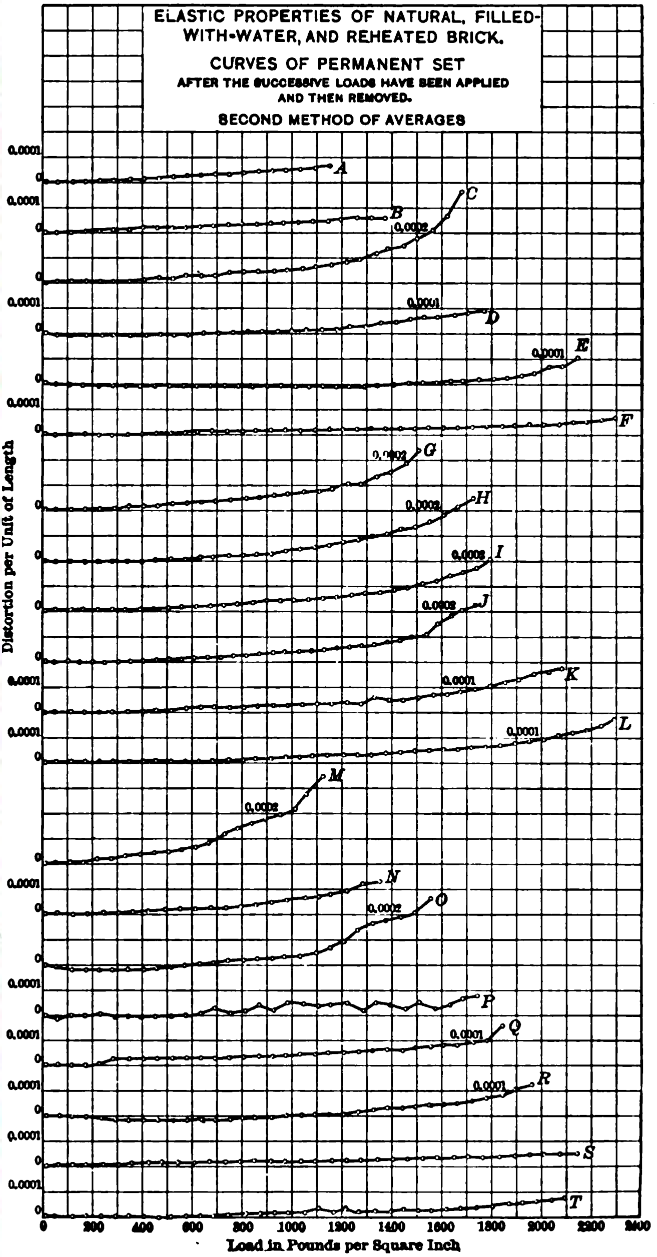
TURRILL ON PHYSICAL PROPERTIES
OF BRICK.





together up to 16 000 lbs., making an average of seven bricks, as shown in Curve *Q*. This method of averaging was followed for the natural, reheated, and filled-with-water brick, each having its own independent averages.

In Figs. 3 and 4 the bricks included in the averages for the several curves are as follows:

Curve.	Numbers of Bricks.
A	Nos. 14, 53, 73, 94, 171, 176 and 185.
B	All bricks in *A*, and No. 26.
C	All bricks in *A*, and Nos. 26 and 100.
D	All bricks in *C*, and No. 104.
E	All bricks in *C*, and Nos. 91 and 104.
F	All bricks in *E*, and No. 25.
G	Nos. 2, 7, 8 and 10.
H	Nos. 2, 4, 7, 8 and 10.
I	Nos. 2, 4, 6, 7, 8, 9 and 10.
J	Nos. 2, 4, 6 and 7 to 11.
K	Nos. 2, 4 and 5 to 11.
L	Nos. 1 to 12.
M	Nos. 97, 101, 104 and 106.
N	Nos. 97, 101, 104, 106 and 108.
O	Nos. 97, 101, 104 and 106 to 108.
P	Nos. 97, 101, 102, 104, and 106 to 108.
Q	Nos. 97, 99 to 102, 104 and 106 to 108.
R	Nos. 97, 99 to 104 and 106 to 108.
S	Nos. 97 and 99 to 108.
T	Nos. 97 to 108.

In the second method, Plate XXIII, only those brick which were loaded up to the same point before removing the mirror micrometers are averaged in one curve. Those bricks (Nos. 97, 101, 104 and 106), carrying a loading of 18 000 lbs. before the removal of the mirror micrometers, are represented by Curve *T*; Curve *S* is the average of all bricks with a loading of 17 500 lbs., which is a single brick, No. 108; Curve *R* is made up of the average of all bricks with a load of 17 000 lbs., and consists of only one brick, No. 107; Curve *Q* is made up of all bricks with a load of 16 000 lbs., and is a single brick, No. 102; Curve *P* is made up of all bricks with a load of 15 000 lbs., and consists of the average of two bricks, Nos. 99 and 100. This method of averaging was followed for the natural, reheated and filled-with-water brick, each having its own independent averages.

On Plate XXIII the bricks included in the averages for the several curves are as follows:

Curve.	Number of Bricks.
A	No. 25.
B	No. 91.
C	No. 104.
D	No. 100.
E	No. 26.
F	Nos. 73, 14, 176, 94, 185, 171 and 53.
G	Nos. 1, 3 and 12.
H	No. 5.
I	No. 11.
J	Nos. 6 and 9.
K	No. 4.
L	Nos. 2, 7, 8 and 10.
M	No. 98.
N	No. 105.
O	No. 103.
P	Nos. 99 and 100.
Q	No. 102.
R	No. 107.
S	No. 108.
T	Nos. 97, 101, 104 and 106.

The apparatus used in this test was very sensitive, so sensitive that even the vibration of the scale beam gave a slightly different reading. After taking the different readings, the differences of readings were computed. The values of the ordinates for the curves of compression were taken as the differences between the initial readings and the successive readings at the loadings of 500, 1 000, 1 500 lbs., etc., while the differences of readings for the curves for permanent set mean the differences between the initial readings and the successive 100-lb. readings, taken after the successive loads of 500, 1 000, 15 000 lbs., etc., had been applied.

By measuring an ordinate on a curve of permanent set and reading the value on the load line, one is able to tell at a glance between what

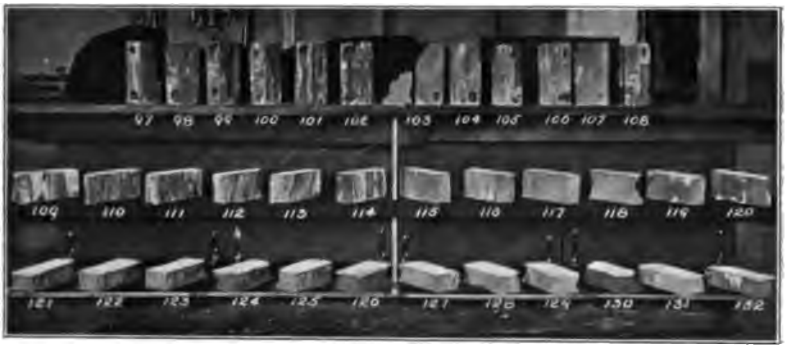


FIG. 1.—COMPRESSIVE TEST OF NATURAL BRICK.
NOS. 97 TO 108, COMPRESSED ON END.
NOS. 109 TO 120, COMPRESSED ON EDGE.
NOS. 121 TO 132, COMPRESSED ON FLAT.

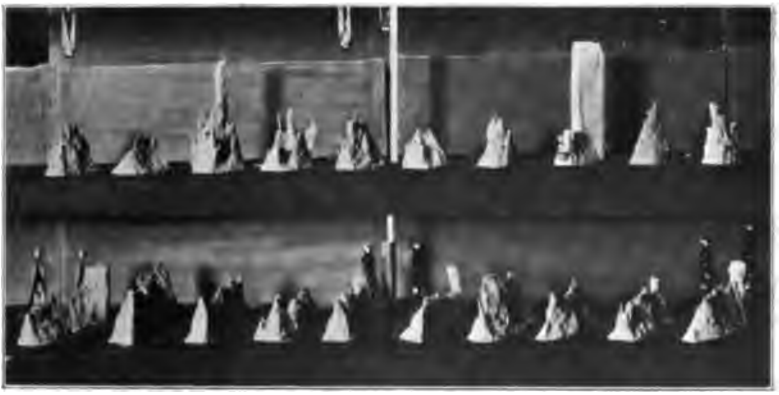


FIG. 2.—COMPRESSIVE TEST OF NATURAL BRICK.
ALL LOOSE PIECES HAVE BEEN REMOVED AFTER CRUSHING.
UPPER ROW, BRICK ON END.
LOWER ROW, BRICK ON EDGE.

two loadings, on the curve of compression, the 100-lb. reading was taken. For example, suppose there is a certain amount of distortion, measured by the length of an ordinate for a 100-lb. loading, located on the load line at 427 lbs. per square inch. This means that after a load of 427 lbs. per square inch had been applied for the curve of compression, a certain amount of permanent set, measured on that ordinate, took place under the following 100-lb. loading.

As a brick is made up of a granular substance, more or less irregularity in the elastic curves might be expected, and that they would be likely to be more irregular in natural brick, where the granular particles are dry and are thus unable to change their relative positions readily on account of friction, than in the case of brick filled with water, where the granular parts are wet and slippery, thus reducing friction to a minimum and allowing the particles to adjust themselves more freely under the respective loadings; or reheated brick, where the particles have become more solidified, and are now more of a solid mass and less granular, causing the brick to increase in stiffness and its particles to change their relative positions more uniformly. By examining the elastic curves, both for compression and permanent set, it will be seen that this statement is well substantiated; the curves for the natural brick being the most irregular, those for brick filled with water the most regular but the weakest in stiffness, while those for reheated brick show the greatest stiffness.

In testing any granular material, the theory is that these particles slide on one another, and change their relative positions under different loadings. Under a certain loading the particles occupy certain positions, but by applying a heavier loading they change their relative positions, causing, for example, the brick to shorten. Now, by releasing this loading, the particles adjust themselves to different positions. Upon applying a still heavier load it is found, that the brick is not distorted as much as under a less loading, showing that the particles, previous to this loading, had taken a firmer position, and that the irregularities of the curve are due to the greater or less compactness assumed by the particles from time to time.

MODULUS OF ELASTICITY.

The modulus of elasticity for compression was found for the initial loading and for every 500 lbs. of loading up to 10 000 lbs. for each brick, thus giving twenty moduli for each brick. The average of these twenty moduli, which run very uniformly in nearly every brick, gave the average for the brick, as recorded in Table No. 9. The average for the twelve brick of each set is also recorded. The lowest modulus obtained in any brick was 500 000 lbs. per square inch, and the highest 2 500 000 lbs. per square inch. It will be seen from Table No. 9 that reheated brick have the highest moduli, while brick filled with water have the lowest.

TABLE No. 9.—MODULI FOR COMPRESSION, FOR NATURAL, FILLED-WITH-WATER, AND REHEATED BRICK.

NUMBERS.			MODULI OF ELASTICITY, IN POUNDS PER SQUARE INCH.		
Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.
97	1	14	1 804 000	1 011 000	1 240 000
98	2	25	540 000	1 350 000	1 056 000
99	3	26	1 598 000	749 000	1 336 000
100	4	53	1 284 000	1 205 000	1 631 000
101	5	73	1 542 000	950 000	1 250 000
102	6	91	1 610 000	827 000	1 323 000
103	7	94	796 000	1 355 000	1 334 000
104	8	100	1 173 000	1 122 000	1 034 000
105	9	104	924 000	904 000	840 000
106	10	171	1 446 000	1 136 000	1 278 000
107	11	176	1 102 000	806 000	2 200 000
108	12	185	1 815 000	894 000	1 323 000
Averages			1 305 000	1 026 000	1 362 000

In computing the moduli, use was made of Hook's Law; that is, the distortion is proportional to the stress, within the elastic limit. Hence the moduli were obtained by dividing the stress by the corresponding distortion per unit of length.

The writer would have liked to determine also the moduli for shear, torsion, bending and tension, in addition to that for compression, if the distortions had been of sufficient magnitude to be measured.

TENSION TESTS OF BRICK.

In making the tension tests the Riehlé, 400 000-lb. testing machine was used, the apparatus consisting essentially of two clamps, one for each end of the brick, on a pivot bearing, as shown in Fig. 5.

The rod, *b*, was attached to the head-block of the testing machine and was allowed considerable lateral motion, so as to adjust itself to a direct pull on the brick during testing. The square bar, *a*, was

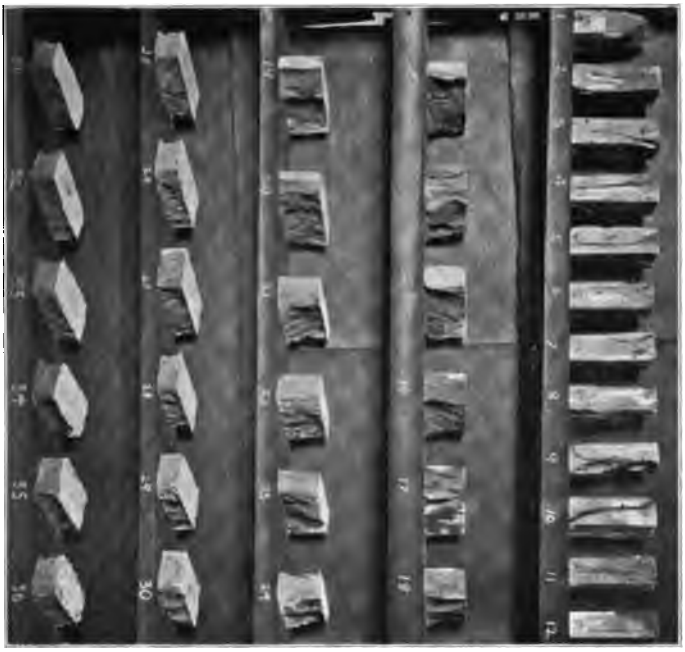


Fig. 1.—Compressive Test: Brick Filled with Water.
Compression on End, Edge and Flat.

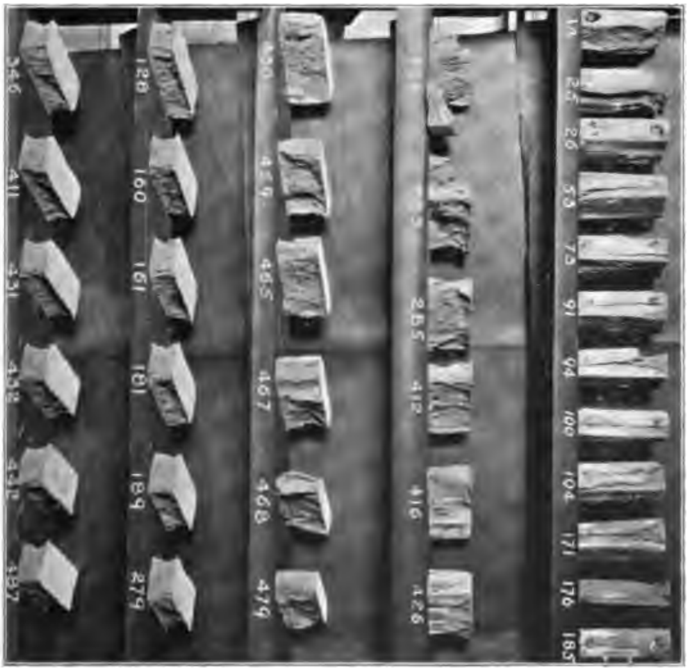
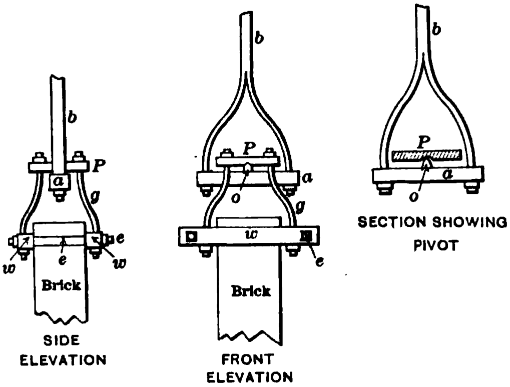


Fig. 2.—Compressive Test: Reheated Brick.
Compression on End, Edge and Flat.

bolted to the spread portion of the rod, *b*, and contained at its middle a pivot, *o*, upon which plate, *P*, and the lower part of the clamp had its bearing. The plate, *P*, rests upon *o* with considerable range of movement, for the sake of direct pull during testing, as shown by the cone-shaped impression in Fig. 5. The bent rods, *g*, were not attached



CLAMPS USED IN TENSION TESTS.

FIG. 5.

TABLE No. 10.—TENSION TESTS OF NATURAL, FILLED-WITH-WATER, AND REHEATED BRICK.

Numbers.			Area of section, in square inches.			Ultimate load, in pounds per square inch.		
Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.
1	25	96	8.89	8.65	8.51	269	201	411
2	26	133	8.53	8.84	8.58	292	189	266
3	27	142	8.77	8.84	8.51	205	219	182
4	28	155	8.72	8.67	8 58	123	218	163
5	29	191	9.11	8.96	8.84	149	112	169
6	30	215	9.08	8.82	8.89	127	204	149
7	31	231	8.82	8.84	8.44	263	242	402
8	32	422	8.67	8.77	8.55	111	186	216
9	33	428	8.65	8.96	8.60	282	234	159
10	34	459	8.89	8.65	8.70	328	278	161
11	35	460	8.65	8.39	8.63	156	238	157
12	36	491	9.23	8.65	8.70	107	188	268
Averages....................			8.83	8.75	8.63	201	209	225

rigidly to the plate, *P*, nor the jaws, *w*, but had sufficient play to allow the two jaws, *w*, to be separated so as to accommodate brick of varying thicknesses. With the brick in place it was fastened securely by means of the two bolts, *e*.

The results of the tension tests are recorded in Table No. 10. A photograph of the fractures is shown in Fig. 1, Plate XXVII. The results show that reheated brick will stand a higher tensile strain than those in either of the other conditions, and that brick filled with water is stronger than natural brick.

Engineers, in general, believe that the cause of failure of brickwork is due largely to tension, and as the tensile strength of brick is so low and the chances for stress under tension so pronounced, it looks as though this was one of its weak points.

BENDING OR TRANSVERSE TESTS OF BRICK.

In this test the brick were tested flat, and had no plaster of Paris or ground surfaces for bearings, but rested directly upon knife-edges in an Olsen testing machine. The distance between the lower knife-edges was 7 ins. and the top knife-edge, to which the load was applied, was 3½ ins. from either bearing.

The results tabulated in this test are the modulus of rupture or stress in the outer fiber, *p*, and the deflection at the center, *D*. In the former case the formula used was $p = \frac{3}{2} \frac{P\,l}{B\,h^3}$*, which is not strictly justified, but customary, in these cross-breaking tests of material having an elastic limit not easily determined. In the latter case, during the test, the deflection should have been measured, and the modulus, *E*, for bending, computed from the formula $D = \frac{1}{48} - \frac{P\,l^3}{E\,I}$†, which formula is true only within the elastic limit. The deflection was so small that the writer was unable to measure it, but, wishing to give some idea of the deflection in brick, he has computed the deflection from the foregoing formula, by using the breaking load and the modulus for compression. The true value of *D* would undoubtedly be smaller than the value obtained, as *P*, within the elastic limit, is somewhat smaller, and the modulus for bending considerably larger, than for compression.

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* Johnson's "Materials of Construction."
† Church's "Mechanics of Engineering."

PLATE XXVI.
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MARCH, 1903.
TURRILL ON PHYSICAL PROPERTIES
OF BRICK.

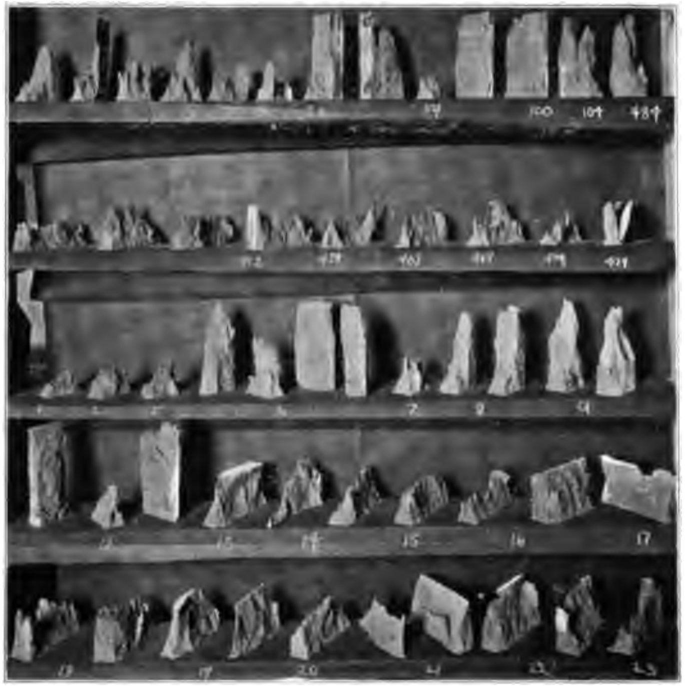

FIG. 1.—COMPRESSIVE TEST:
REHEATED BRICK AND BRICK FILLED WITH WATER.
ALL LOOSE PIECES HAVE BEEN REMOVED AFTER CRUSHING.
TWO UPPER ROWS: REHEATED BRICK.
THREE LOWER ROWS: BRICK FILLED WITH WATER.

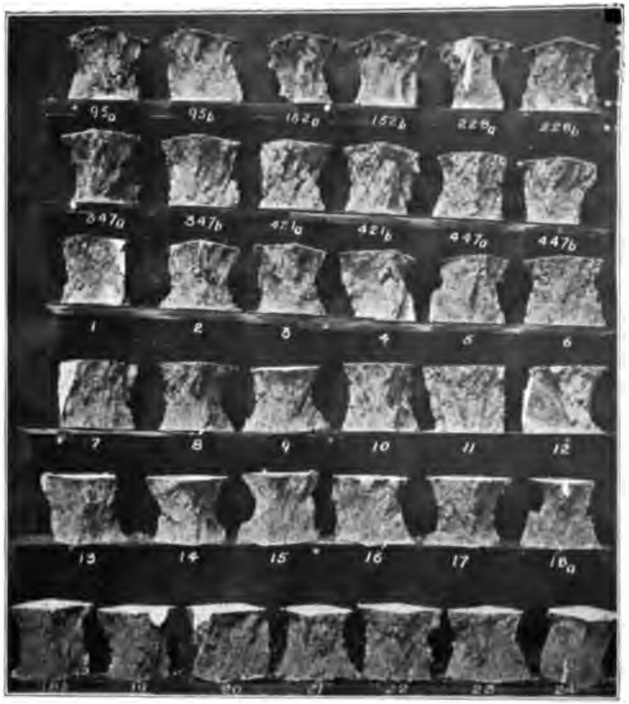

FIG. 2.—COMPRESSIVE TEST:
BRICK CUBES.
NOS. 95a TO 447b: REHEATED CUBES.
NOS. 1 TO 12: NATURAL CUBES.
NOS. 13 TO 24: CUBES FILLED WITH WATER.

In the foregoing formulas:

P = load at center;

l = length of brick;

b = width of brick;

h = height of brick;

I = moment of inertia of the section.

The theory has been advanced that the fibers above the neutral axis of a simple beam under any loading are in compression, while those below are in tension. A comparison of the results shown in Table No. 10 with those in Tables Nos. 2 to 8, for tension and compression, respectively, will show that bricks are weaker in the former tests than in the latter. From this, it would be inferred, naturally, that, as the vertical shear at the center is zero, the brick broke in tension. Upon looking at Table No. 11 it will be seen that the stress in the outer fiber is a little more than half the total load, and is larger than that caused by tension. The following question now arises. "The excess of stress in the outer fiber, over that of tension, is taken up in what forms of distortion?" This excess of stress, in all probability, is taken up mostly in compression, while a small portion of it, undoubtedly, is absorbed by horizontal shear.

TABLE No. 11.—TRANSVERSE OR BENDING TESTS OF NATURAL, FILLED-WITH-WATER, AND REHEATED BRICK.

NUMBERS.			TOTAL LOAD AT CENTER, IN POUNDS.			STRESS IN OUTER FIBER UNDER BREAKING LOAD, IN POUNDS PER SQUARE INCH.			DEFLECTION AT THE CENTER UNDER BREAKING LOAD, IN INCHES.		
Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.
37	61	11	1 720	1 280	1 060	921	696	509	0.0026	0.0025	0.0018
38	62	89	1 060	1 440	1 800	537	736	971	0.0015	0.0026	0.0026
39	63	202	1 380	1 050	1 270	789	542	644	0.0021	0.0019	0.0017
40	64	260	920	1 370	2 000	459	788	1 097	0.0012	0.0026	0.0029
41	65	271	1 410	1 890	1 530	782	987	782	0.0023	0.0032	0.0021
42	66	370	1 470	1 500	1 510	772	809	821	0.0021	0.0029	0.0022
43	67	401	1 180	1 690	1 190	637	945	642	0.0018	0·0033	0.0017
44	68	488	2 000	1 720	1 880	1 125	1 019	730	0.0031	0.0038	0.0019
45	69	465	1 990	1 680	1 770	1 131	906	669	0.0032	0.0032	6.0015
46	70	472	1 990	1 580	1 980	1 101	775	1 077	0.0031	0.0027	0·0029
47	71	480	1 820	1 720	2 000	1 026	797	1 056	0.0029	0.0026	0.0027
48	72	488	1 990	1 090	1 960	1 126	495	991	0.0031	0.0017	0.0025
Averages.....			1 580	1 490	1 620	863	788	832	0.0024	0.0027	0.0022

SHEARING TESTS OF BRICK.

In these tests it will be noticed, upon referring to Table No. 12, that each brick was divided into halves, and that a record of the test of each half is shown. It will be seen that there is quite a difference in the strength of the two halves, showing that a single brick in itself is not perfectly homogeneous.

TABLE No. 12.—SHEARING TESTS OF NATURAL, FILLED-WITH-WATER, AND REHEATED BRICK.

NUMBERS.			AREA OF SECTION, IN SQUARE INCHES.			ULTIMATE LOAD, IN POUNDS PER SQUARE INCH.								
						First half-brick.			Second half-brick.			Averages.		
Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.	Natural.	Filled with water.	Reheated.
1	25	9	8.58	8.96	8.89	583	138	349	636	179	562	610	158	455
2	26	58	8.89	8.28	8.65	371	535	497	367	705	514	369	620	505
3	27	129	8.82	8.58	8.58	380	186	262	330	385	271	355	286	266
4	28	212	8.77	8.00	8.65	381	800	509	285	625	512	333	712	510
5	29	236	8.77	8.79	8.51	274	210	544	310	319	670	292	265	607
6	30	261	8.65	8.69	8.84	453	685	543	763	353	430	608	519	486
7	31	265	8.84	8.77	8.68	279	319	513	358	506	618	316	412	565
8	32	450	8.34	8.65	8.44	528	309	461	507	116	409	518	213	435
9	33	469	8.44	8.84	8.65	585	236	370	476	411	403	530	324	386
10	34	475	7.93	8.46	8.79	908	355	165	542	693	198	725	524	182
11	35	477	8.13	8.27	8.68	492	293	554	223	235	292	358	264	423
12	36	495	8.46	8.77	8.89	212	253	484	449	380	579	330	316	526
Averages....			8.55	8.56	8.68	454	360	438	437	409	454	445	384	446

It is regretted that the moduli for shearing could not be obtained, for the reason that the deflections were so small that they could not be measured.

The fractures produced by these tests are shown in Fig. 2, Plate XXVII. The machine used was the Riehlé, 400 000-lb. testing machine, to which was attached the apparatus shown in Fig. 6.

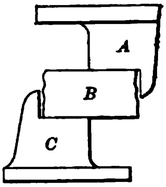

FIG. 6.

The upper shear is denoted by *A*, which was attached to the upper head-block, while the lower shear is marked *C*, and was attached to the bed-plate. The face of each shear is on the same vertical plane, which is the center of the machine. The half-brick to be tested is shown in place at *B*.

PLATE XXVII.
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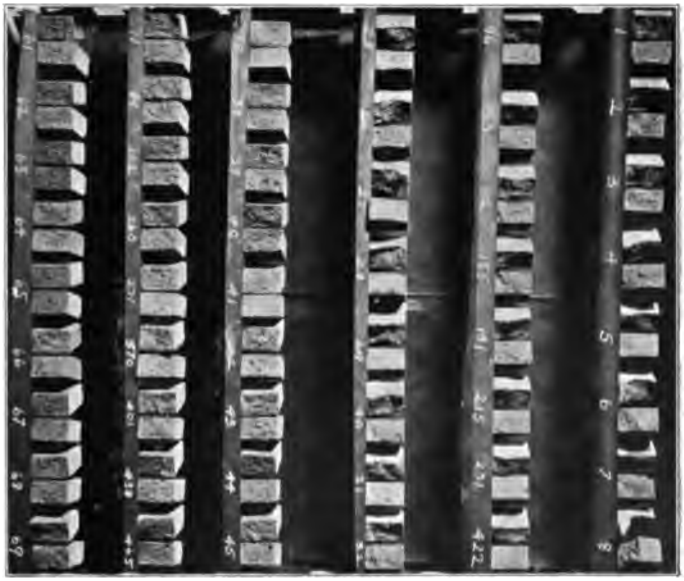

Fig. 1.—Tension and Bending of Brick.
Upper Three Rows in Tension.
Lower Three Rows in Bending.

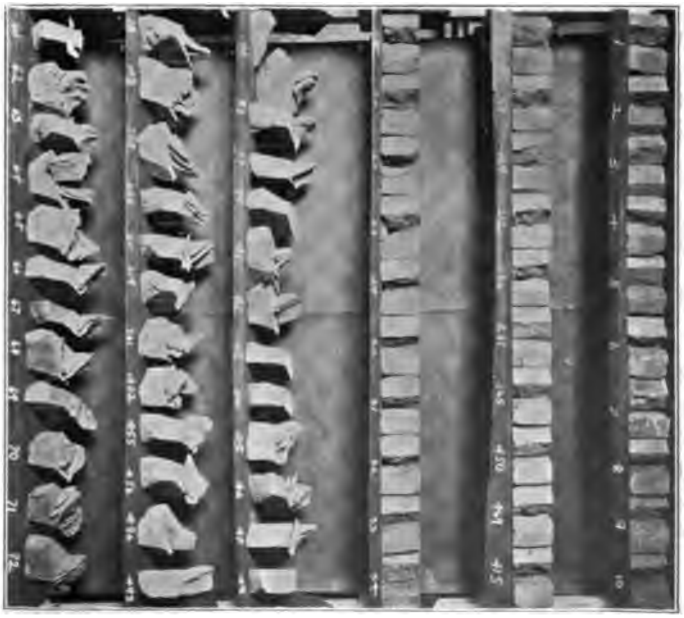

Fig. 2.—Shear and Torsion of Brick.
Upper Three Rows in Shear.
Lower Three Rows in Torsion.

TORSIONAL TESTS OF BRICK.

As far as the writer knows, brick has never before been tested in this manner. Although, in actual brick construction, the stresses produced under this form of strain are very small and practically negligible, it was thought that it would be of interest to make such a test; thus completing a set of tests of all the forms of strain to which a brick can be subjected under ordinary engineering operations.

In conducting this test, the Thurston Autographic Testing Machine, sometimes spoken of as Thurston's Torsion Testing Machine, was used.*

The machine consists, essentially, of a pendulum, a drum, a curved guide by which a pencil arm is moved and traces upon the drum a permanent record, as shown in Figs. 9, 10 and 11. The test piece is held in place between the pendulum and the drum by two jaws.

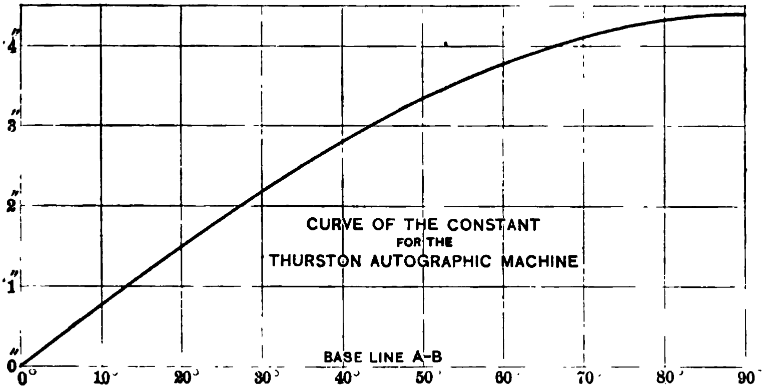

FIG. 7.

In carrying out the torsional tests the writer first standardized or found the constant of the machine, as follows: A piece of paper was first placed in the drum while it was unclamped on the shaft, with the upper end of the pencil rod in the hollow of the curved guide and the pencil on the drum, while it was turned through 180°, more or less, thus ruling the base line *A B*, as shown in Fig. 7, from which the ordinates are measured. As the pendulum was raised to a horizontal position, the pencil traced, on the paper in the drum, which was now clamped, the curve of the constant, as shown in Fig. 7. The pendulum in the horizontal position was found to weigh 121 lbs. at the center of gravity of the weight, which was 4.16 ft. from the center of the head. The circumference of the drum was found to be 36 ins., which indicated that each inch on the base line was equivalent to an angular distance of 10° for both pencil and pendulum.

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* A description and illustrations of the working parts of this machine may be found in Thurston's "Materials of Engineering," pp. 378 *et seq.* Reference may also be made to Carpenter's "Experimental Engineering," p. 96.

Sufficient data having been obtained, the constant of the machine was derived, as follows:

$P\ a = 121 \text{ lbs.} \times 4.16 \text{ ft.}$

$= 503.36$ foot-pounds, the moment for the 90° position of the pendulum.

The length of the ordinate for the 90° position is 4.4 ins., and, as the constant of the machine is 503.36 foot-pounds, 4.4 ins. = 114.4 foot-pounds per inch of ordinate. The presence of some journal friction would necessitate this being accounted for in determining the final results. The pull at the center of the weight and 4.16 ft. from the center of the drum, to overcome the journal friction and hence pull the pendulum from its vertical position, was equivalent to $1\frac{7}{8}$ lbs. The constant for friction, or the frictional moment, is $1\frac{7}{8}$ lbs. × 4.16 ft. = 7.80 foot-pounds.

The test piece being rectangular in section, the theoretical results obtained by Grashof were taken. See Fig. 8.

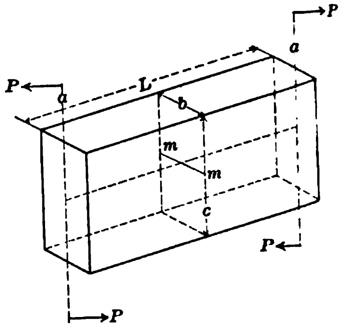


FIG. 8.

Let L = length of brick actually subjected to torsion;

P_s = maximum shearing stress in the outer fiber (which will occur at the middle of the long side, at m) $= \frac{9}{2} \times \frac{P\ a}{b_2} c$;

α = angle of torsion, which (in π measure), for a length, L,

$$= \frac{9}{2} \times \frac{P\ a\ L}{E} \times b^2 + \frac{c^2}{b^3} c^3.$$

Of course, these formulas only apply if the elastic limit is not passed. To use them beyond this limit gives only approximate results, but, nevertheless, this is the best that can be done, under the circumstances.

TABLE No. 13.—Torsional Tests of Natural, Filled-with-Water, and Reheated Brick.

Shearing Stress in the Outer Fiber.

Numbers.			Natural brick.		Brick filled with water.		Reheated brick.	
Natural.	Filled with water.	Reheated.	Constant.	Stress under breaking load, in pounds per square inch.	Constant.	Stress under breaking load, in pounds per square inch.	Constant.	Stress under breaking load, in pounds per square inch.
37	61	13	0.229	414	0.219	359	0.223	559
38	62	143	0.225	526	0.229	503	0.233	470
39	63	203	0.219	532	0.229	462	0.223	324
40	64	206	0.225	402	0.221	258	0.242	659
41	65	211	0.251	750	0.221	261	0.163	325
42	66	219	0.247	817	0.225	368	0.217	422
43	67	388	0.253	626	0.231	370	0.169	410
44	68	402	0.249	724	0.275	916	0.229	603
45	69	455	0.233	552	0.273	759	0.213	863
46	70	456	0.251	658	0.231	598	0.213	420
47	71	489	0.244	517	0.264	734	0.213	410
48	72	493	0.238	790	0.239	632	0.219	381
Averages			0.239	609	0.238	518	0.213	487

TABLE No. 14.—Torsional Tests of Natural, Filled-with-Water, and Reheated Brick.

Modulus of Elasticity for Shearing.

Number.			Natural brick.		Brick filled with water.		Reheated brick.	
Natural.	Filled with water.	Reheated.	Constant.	Modulus, in pounds per square inch.	Constant.	Modulus, in pounds per square inch.	Constant.	Modulus, in pounds per square inch.
37	61	13	6.429	49 900	6.021	32 900	6.127	115 200
38	62	143	6.251	39 800	6.271	137 900	6.524	82 200
39	63	203	5.998	36 400	6.415	103 400	6.127	28 100
40	64	206	6.227	14 200	6.125	45 200	6.497	55 900
41	65	211	7.175	13 800	6.097	32 000	4.229	36 100
42	66	219	6.999	29 200	6.227	27 200	5.924	55 400
43	67	381	7.210	21 800	6.394	76 900	4.391	53 300
44	68	402	7.015	26 000	7.961	45 500	6.360	45 700
45	69	455	6.647	21 700	7.889	59 900	5.780	104 100
46	70	456	7.202	19 400	6.493	106 100	5.847	115 200
47	71	486	7.033	25 900	7.620	46 300	5.803	89 300
48	72	493	6.698	19 300	6.725	42 700	6.044	90 200
Averages			6.741	26 500	6.687	63 000	5.810	68 400

Tables Nos. 13 and 14 show that there has been found by torsional tests, shearing stresses in the outer fiber, and the modulus of elasticity for shearing, in pounds per square inch, under the breaking load, the values in these tables being for the ordinates shown in dotted lines in Figs. 9, 10 and 11.

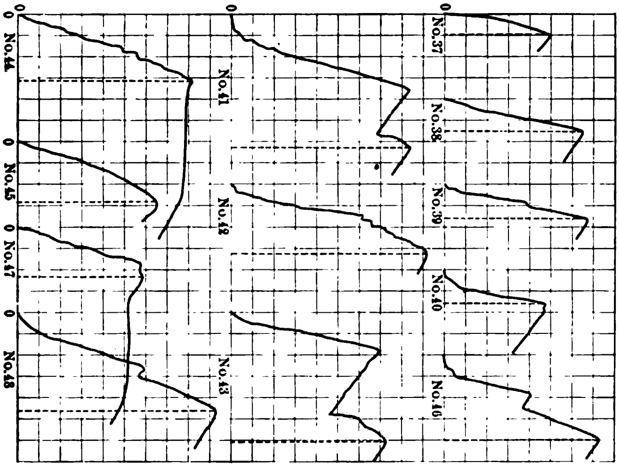
In arranging these two tables, both constants and stresses were given for each set of brick, thus enabling the reader to find the stresses for other ordinates of the curves of torsion, by means of the constant and measurement of ordinates and abscissas. The constant in the table of shearing stresses is equal to $\frac{9}{2} \times \frac{1}{b^2 c}$ which is a portion of the formula $p\sigma = \frac{9}{2} \times \frac{Pa}{b^2 c}$; while the constant in the table of moduli is equal to $\frac{9}{2} \times \frac{L}{\alpha_1} \times \frac{b^2 c^2}{b^3 c^3}$ (α_1 being the value of 10°, expressed in π measure), which is a portion of the formula

$$\alpha = \frac{9}{2} \times \frac{P a L}{E\sigma} \times \frac{b^2 c^2}{b^3 c^3} = \alpha_1$$

times the length, in inches, of the abscissa in question. The shearing stress for any ordinate, therefore, is the constant of the machine, expressed in inch-pounds, multiplied by the length of the ordinate, in inches, plus the frictional constant, in inch-pounds, which sum is $P a$, in the formula, and is multiplied by the constant in Table No. 13. The modulus for any ordinate is $P a$, divided by the corresponding abscissa, multiplied by the constant in Table No. 14.

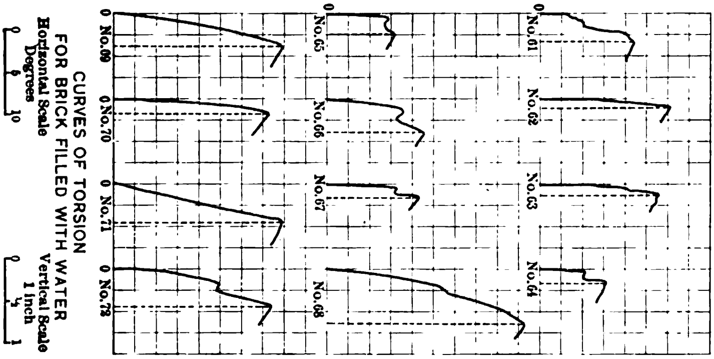
The photograph, Fig. 2, Plate XXVI, shows the specimens which were submitted to torsional tests—natural brick in the upper row, reheated brick in the middle row, and brick filled with water in the bottom row. In all these three tests it will be seen that the corners gave way first, followed in most cases by a series of thin parallel curved planes. In no case did the failure take place in the central portion of the brick, nor, with such a brittle material, is it ever likely to take place there, unless the area of this portion is reduced considerably from what it is at the points where the test piece is held.

The distance the grips extend into the brick would have some bearing upon the number of parallel planes broken off and the distance of these planes from the corner. The farther the grip extends into the test piece, the more remote from the corner will the planes break off,



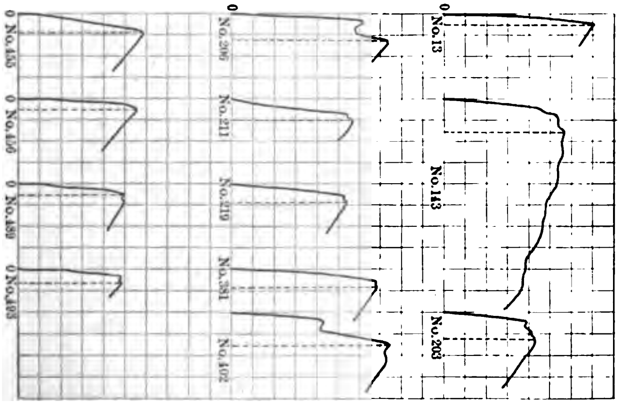
CURVES OF TORSION FOR NATURAL BRICK

FIG. 9.



CURVES OF TORSION FOR BRICK FILLED WITH WATER

FIG. 10.



CURVES OF TORSION FOR REHEATED BRICK

FIG. 11.

and the greater will be their number, while the distance between the parallel planes remains the same. The tendency in the brick is to break off at both of its corners at one end and turn around, with the center of each end as an axis, as in Brick No. 46, in Fig. 9. Sometimes the corners on ends diagonally opposite each other, or on the same edge, will fail first, leaving the brick between the grips, in a skew or square, respectively, as shown in Bricks Nos. 219 and 66, Figs. 10 and 11. In the foregoing tests the grip or jaw extended into the brick, which was held in place by wedges.

By examining the curves of torsion in Figs. 9, 10 and 11, it will be seen that there is more or less irregularity in the curves; indicating that the brick failed all at once or by degrees. The most regular curves are where they failed at once; the irregular curves are where they failed by degrees. The more the irregularity of the curve, the greater number of stages during failure, and, hence, the greater number of thin parallel planes.

By studying Tables Nos. 13 and 14, and the curves of torsion, it will be seen that the natural brick stood the highest in shear, and the reheated brick in moduli. The highest special brick in shear is No. 68, tested filled with water; while the highest in moduli is No. 62, which was also tested filled with water. It will be noticed that those bricks having curves with the longest ordinates are the highest bricks in shear, while those which have the shortest abscissas are the largest in moduli.

CONCLUSION.

In comparing the tables for the strength of the brick under different strains, one finds the following order of increase in strength, namely, tension, shear, torsion, bending, compression.

This order would naturally lead one to believe that the least important test was that of compression, and the most important that of tension, the others occupying places in the order given. But this does not follow, necessarily, for strains set up in certain directions are more marked than in others. For example, torsion would stand third in importance if rated in this way, but the writer believes this to be the least important test, because in brickwork torsional strains are less likely to be set up than any other form of strain.

The most important tests are tension and compression, as these strains are more likely to occur than any others, and, of these, tension is the more important, as it is the weaker stress, and, when brickwork fails, bulging is brought out very prominently, and this produces tensional strains, and, to a less marked degree, bending and shear. Of the two remaining forms, bending is more important than shear, as strain along this line is more likely to occur than in shear, although shear shows the weaker stress.

As to the best kind of brick to use, the tables and the curves of distortion show results decidedly in favor of reheated brick; but, taking into account the expense of preparing reheated brick and the loss of 12% of them, it would be cheaper to use enough extra natural brick to make up the excess of strength found in reheated brick, unless the reheating has been done in a conflagration. Natural brick and brick filled with water show about the same results, so that, in general, the water does not impair the strength of the brick.

In the compression test, the brick on flat are the strongest, while the brick cubes are the weakest, and the brick on end are weaker than those on edge. In this test the pieces are 2, 4 and 8 ins. in height, from which the strength for a square inch for the respective heights can be computed. The question comes up: What would be the strength of each of these specimens if it were only 1 in. high? The writer has assumed that the specimens would increase in strength per square inch as many times as the specimen is inches in height, and has, as a result, the figures given in the columns headed, "Equivalent ultimate load per unit of height, in pounds per square inch." The results show that this assumption is wrong, and that some other ratio of the height exists. What this is can be found more satisfactorily by tests than by assumptions.

By looking at the shearing and torsional tests, Tables Nos. 12 and 13, respectively, it is seen that those in Table No. 12 are for direct shear, and those in Table No. 13 are for shear in the outer fiber, caused by torsional strain. In the case of reheated brick, the stresses are about the same in both tables, those in No. 13 being a little larger, while the greatest difference is in the natural brick, those in Table No. 13 being about one and one-half times those found in Table No. 12. In these two tables the important test is that of direct shear.

Vol. XXIX. MARCH, 1903. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

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A SMALL ROCK-FILL DAM.

By H. de B. Parsons, M. Am. Soc. C. E.

To be Presented May 6th, 1903.

The rock-fill dam described in this paper was designed by the writer for George Crocker, Esq., to impound a gravity water supply for his estate at Darlington, near Ramseys, New Jersey.

The site selected was at the head of a ravine where the hills widened out, forming a natural bed for a lake. The site was about 250 ft. above the farm buildings in the valley of the Ramapo River, and about 65 ft. above the point selected for the new residence.

The small brook running down the ravine had a probable summer average flow of from 9 to 10 cu. ft. per second. During extreme freshets, this flow was increased rapidly, probably to sixty or seventy fold, as, owing to the rocky formation of the hills in this locality, the run-off and rainfall are nearly equal.

A dam height of 20 ft. was decided upon as being sufficient to impound about 11½ acres of lake surface. The length along the crest was 235 ft.

Rock outcropped on the east side of the brook, but disappeared on the west side. Test pits dug on the latter side showed the covering to consist of: Gravel and soil, 1 ft. 6 ins.; mixed sand, gravel and

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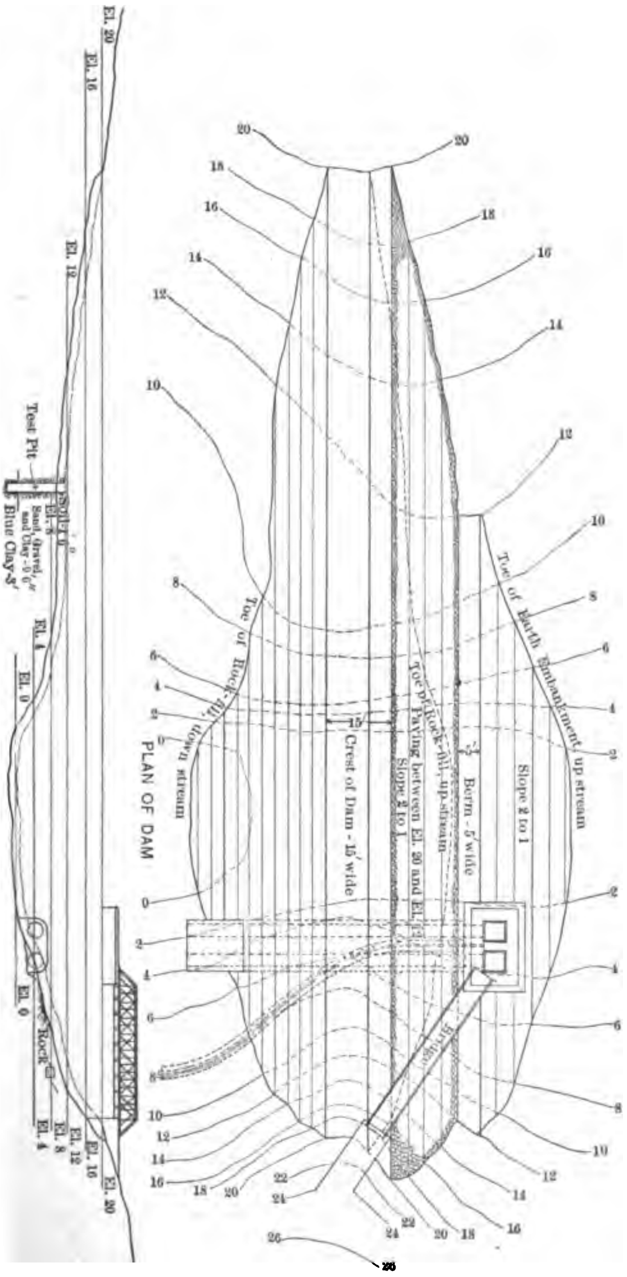

ROCK-FILL DAM
AT
RAMSEYS, NEW JERSEY
FOR
GEORGE CROCKER, Esq.

Fig. 1.

clay, 9 ft. 6 ins., and blue clay beneath. The outcropping rock was found to be seamy and somewhat broken. The approach to the site, by road, was difficult, due to the steep incline. The problem, therefore, was the design of some form of dam which would be easy to erect and would require the least amount of falsework or contractor's apparatus.

Under the foregoing conditions it was decided that a rock-fill dam, backed with earth on the water side, was the most expedient. Furthermore, the cost of such a dam was estimated to be less than one-third of the cost of a masonry dam of equal size.

The general plan and down-stream elevation are shown in Fig. 1. the cross-section in Fig. 2, and the gate-house in Fig. 3

The rock on the east bank was blasted out, so as to provide a foundation for the gate-house, and the surface rock was prepared to receive the rock-fill. All seams and cracks in the rock were pointed carefully with Portland cement.

The earth and soil, for a depth of about 18 ins., was removed from the site of the dam between the up- and down-stream toes. A trench, about 30 ins. deep, was then dug along the up-stream toe, and a double row of sheet-piles, with lapped joints, was driven. These piles were 3 ins. thick, and were driven until rock was reached or the end entered the blue-clay stratum. In no place did they exceed 14 ft. in length.

The gate-house and blow-off pipes were then constructed. The gate-house was built of rubble masonry, laid in Portland cement mortar consisting of 1 unit by measure of cement to 2½ units of sand. The grooves for the gates and screens were six-hammered. The top was finished with a cut-stone coping, filled flush at the center with concrete.

The blow-off pipes were 36 ins. in diameter, and were of steel, ½ in. in thickness, stiffened every 10 ft. by 3 x 3-in. angles, which also acted as water stops. The sheets were single-riveted and caulked. These pipes were bedded in concrete, which was tamped closely under and around them.

Ridges were left in the concrete to act as water stops and to hold the rock fill and earth in place.

When sufficient work had been accomplished on the gate-house and blow-offs, the rock fill was commenced. By thus regulating the

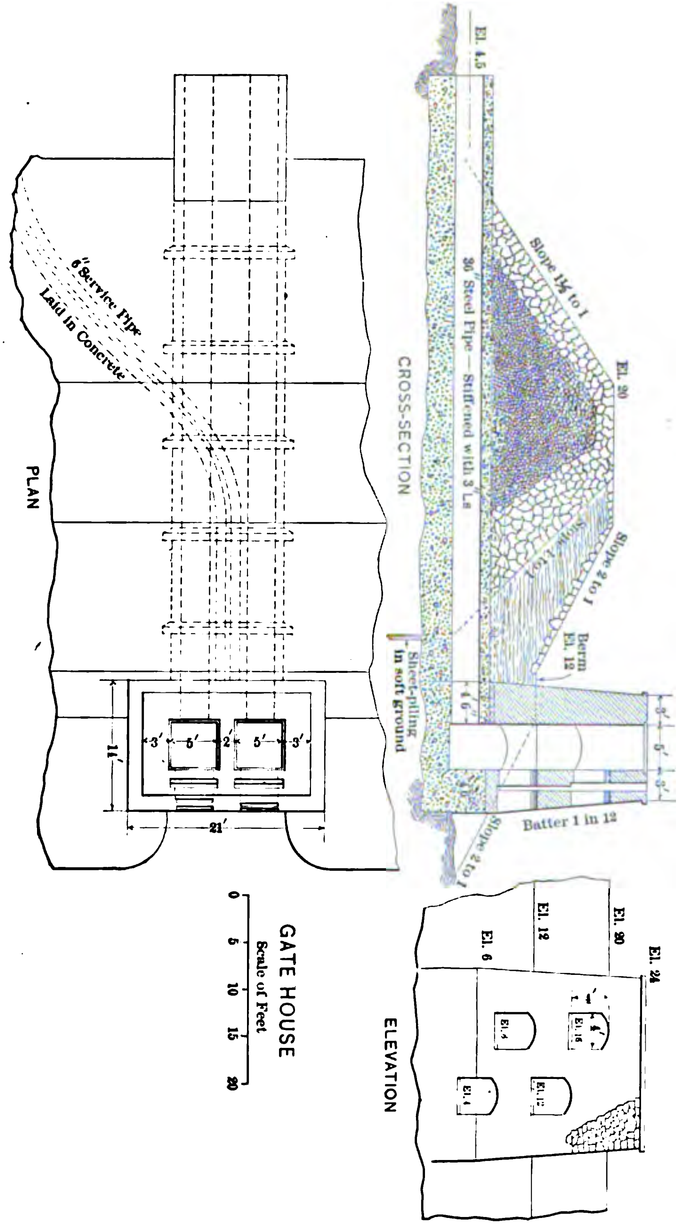
PLAN
6" Service Pipe
Laid in Concrete
3'
5'
2'
5'
3'
11'
21'
CROSS-SECTION
El. 4.5
30" Steel Pipe — Stiffened with 3 Ls
Slope 1½ to 1
El. 20
Slope 1 to 1
Slope 2 to 1
Berm
El. 12
Sheet-piling
in soft ground
4'6"
4'6"
3'
5'
3'
Batter 1 in 12
Slope 2 to 1
GATE HOUSE
Scale of Feet
0
5
10
15
20
ELEVATION
El. 20
El. 12
El. 6
El. 24
El. 4
El. 16
El. 4
El. 12
4'
4'

FIG. 2.

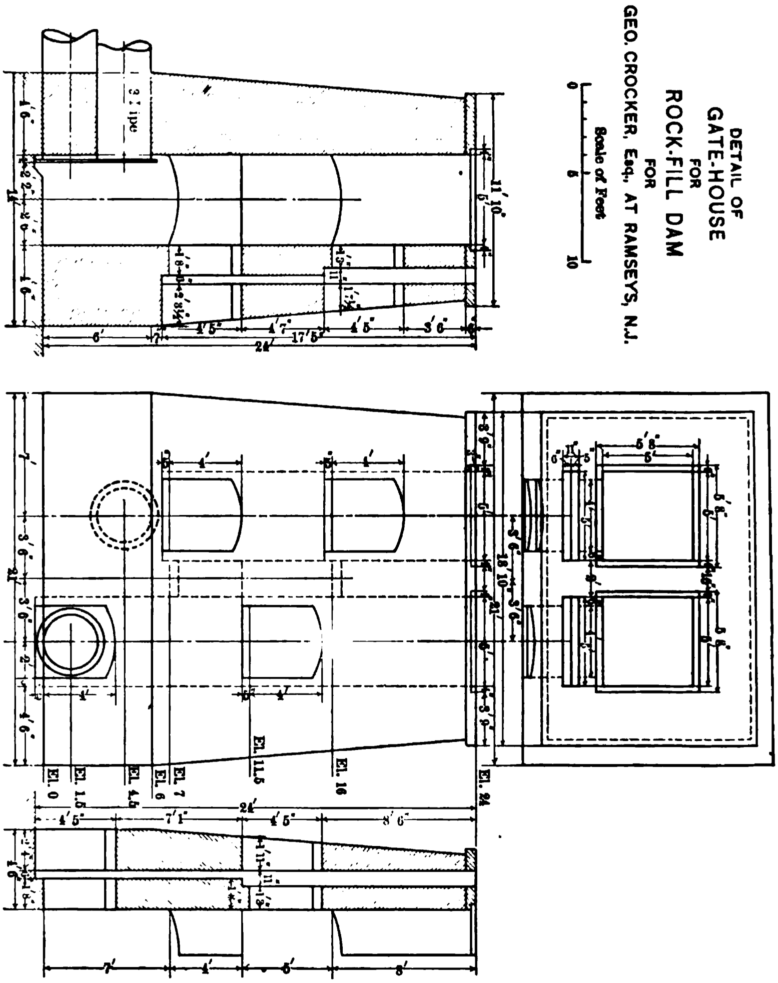
DETAIL OF
GATE-HOUSE
FOR
ROCK-FILL DAM
FOR
GEO. CROCKER, Esq., AT RAMSEYS, N.J.
Scale of Feet
0
5
10
Pipe
EL. 0
EL. 1.5
EL. 4.5
EL. 6
EL. 7
EL. 11.5
EL. 16
EL. 24
24′
17′5″
11′10″
18′10″
21′

Fig. 8.

PLATE XXVIII.
PAPERS, AM. SOC. C. E.
MARCH, 1903.
PARSONS ON ROCK-FILL DAM.

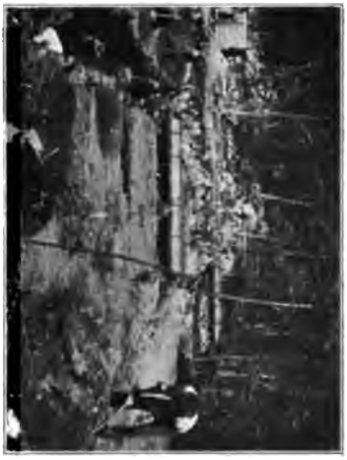

FIG. 1.—PROGRESS OF WORK, JULY 1ST, 1902.

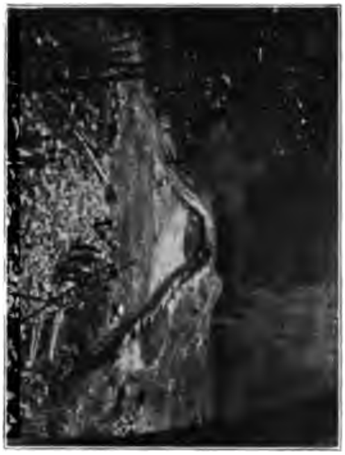

FIG. 2.—PROGRESS OF WORK, AUGUST 1ST, 1902.

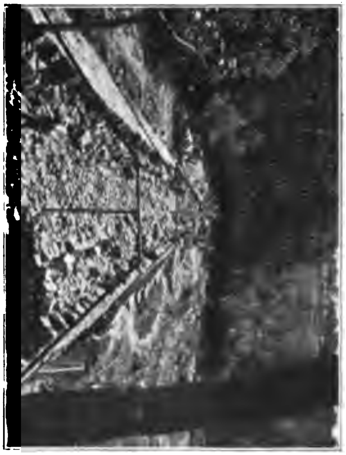

FIG. 3.—PROGRESS OF WORK, SEPTEMBER 11TH, 1902.

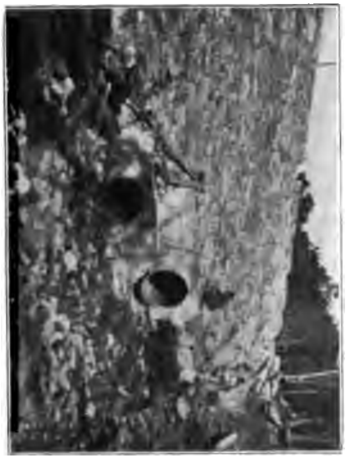

FIG. 4.—PROJECTING ENDS OF BLOW-OFF PIPES.

work, the brook was allowed to follow its natural course until the rock fill began to dam it up, when the water was passed through the lower of the blow-off pipes. The work could thus be carried on from beginning to end in a dry state and without the use of coffer-dams or other falsework.

The rock fill was made from stone, blasted out of the hillside, loaded on wagons and simply dumped on the work. Care was taken to build up the wall in horizontal layers, and to use a sufficient quantity of small stones and spawls to fill the voids as full as possible. The stone carts were driven over the work as it progressed, in order to help jar and pack the stones. The stones were all cleaned carefully before being put into the wall; and, in shape, were rough and jagged, all smooth stones being rejected.

The best-shaped stones were reserved for hand placing on the two faces. On the down-stream face, the hand packing was about 5 ft. thick, and on the up-stream face from 5 ft. at the crest to 10 ft. at the toe. This hand packing resembled dry rubble masonry, and was carried up a little in advance of the center filling. Its object on the up-stream face was to help make the dam water-tight by offering narrow and broken joints, which would retain the matter carried in by leakage. On the down-stream face, the object was to permit the dam to overflow without material injury. No spillway was provided in the crest, because the dam was intended to be used as a driveway during the summer season. It is only at rare intervals that the dam is expected to overflow, and the long crest will allow ample way for the water, which will not be more than a few inches in depth on the crest, even at periods of worst flood. Such floods last only a short time. Should injury be done by ice or overflow, the damage can be easily repaired.

The earth fill consisted almost entirely of clay, which, luckily, was more abundant than had at first been anticipated. It was carried up in horizontal layers, about 6 ins. in thickness, and each layer was well watered and rolled with a grooved two-horse roller. The water side was paved above the berm with flat stones, laid so as to have an average depth of 12 ins. This was done as a protection against ice.

At the east end of the crest, a rubble stone abutment was built, and a light, steel-truss bridge extended to the top of the gate-house.

The water service pipe was of lap-welded, wrought iron, 6 ins. in diameter, with the lengths joined by heavy flanges, having faces turned true, and bedded in the concrete mass with the blow-offs.

The work was commenced on May 21st, and completed on November 8th, 1902. When finished, the dam was practically water-tight. There was a slight leak at the lower of the blow-off pipes, but this diminished in volume rapidly, and ceased in about thirty days.

Fig. 1, Plate XXVIII, shows the progress of the work on July 1st. The cut-off trench for the sheet-piling is seen on the left, and the blow-off pipes in the back-ground.

Fig. 2, Plate XXVIII, shows the progress of the work on August 1st. The sheet-piling is seen clearly on the right, and the rock fill in the foreground.

Fig. 3, Plate XXVIII, shows the progress of the work on September 11th. The construction of the dam is seen in this photograph. The hand-placed material on both up- and down-stream faces, with the loose rock fill in the center, is easily distinguishable.

Fig. 4, Plate XXVIII, shows the down-stream ends of the blow-off pipes embedded in the concrete and projecting through the dam. The photograph also shows the character of the hand-placed work.

Fig. 1, Plate XXIX, shows the progress of the work on October 21st. The commencement of the earth embankment will be noticed on the right.

Fig. 2, Plate XXIX, shows the gate-house structure on October 21st.

Figs. 3 and 4, Plate XXIX, show the completed structure, with the pond about half full.

The dimensions of the dam are:

Length on crest	235 ft.
Height at center	20 "
Width of crest, total	15 "
" " " masonry	10 "
" " " earth	5 "
Slope of masonry, up-stream face	1 on 1
" " " down-stream face	1 on 1½
" " earth embankment	1 on 2

The contract price was $8 700.

The quantities, and a close estimate of the unit prices, are given in Table No. 1. These unit prices include all the contractor's expenses, but not his profit, as the work appeared to cost all of the contract price.

PLATE XXIX.
PAPERS, AM. SOC. C. E.
MARCH, 1903.
PARSONS ON ROCK-FILL DAM.

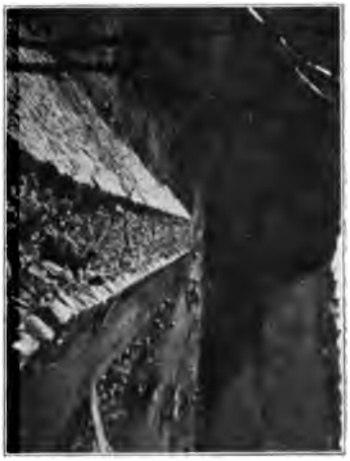

Fig. 1.—Progress of Work, October 21st, 1902.

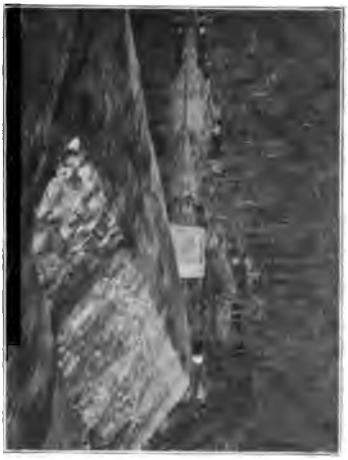

Fig. 3.—The Completed Dam.

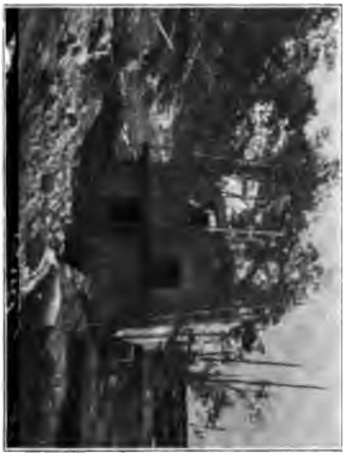

Fig. 2.—The Gate-House on October 21st, 1902.

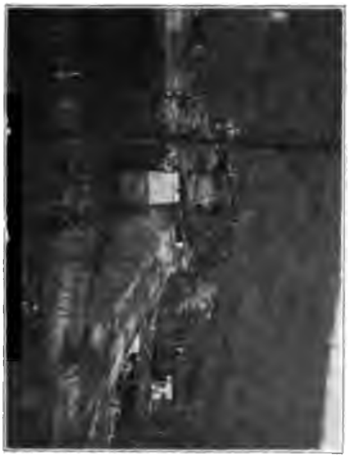

Fig. 4.—The Completed Dam.

TABLE No. 1.

Item.	Quantity.	Unit Price.
Earth excavation	794 cu yds.	$0.30
Earth embankment, including rolling	12 570 " "	0.48
Rock excavation	210 " "	1.60
Rock fill, core filling	1 642 " "	0.45
Rock fill, hand-packed	1 853 " "	0.95
Timber, sheet-piling	18 200 ft. B. M.	54.00
Timber, gates, bridge floor, etc.	1 200 " "	80.00
Concrete	120 cu. yds.	7.80
Paving	142 " "	1.70
Rubble masonry	157 " "	8.10
Fine-hammered facing	186 sq. ft.	0.80
Steel bridge	3 000 lbs.	0.10
Blow offs and service pipes	16 150 "	0.10
Gate-valves, two 36-in. and one 6-in	3	220.00
Hand-power winch	1	40.00

The contractor was Mr. Watson E. De Baun, of Tuxedo, New York, to whom, and to Mr. James White, his foreman in charge, credit is due for the faithful way in which they carried out the intent of the specifications. The writer also acknowledges his thanks to William A. Cattell, M. Am. Soc. C. E., for some suggestions, and to H. B. Atkins, Assoc. M. Am. Soc. C. E., and Mr. John W. Doty for their supervision of the construction.

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DEFLECTIONS OF BEAMS WITH VARIABLE MOMENTS OF INERTIA.

By C. W. Hudson, M. Am. Soc. C. E.

To be Presented May 6th, 1903.

The determination of the deflections for the special types of open-webbed, elastic frameworks often met with in the practice of the bridge engineer has received much attention, and very exact solutions are made for these problems by both graphical and analytical methods.

The determination of the deflections for solid-webbed girders, which is of equal theoretical interest and often of great practical importance, however, has been confined chiefly to girders with a constant moment of inertia, and such determinations have usually been made by means of the equation of the elastic curve. It is the purpose of this paper to give a more general method for determining the deflections of solid-webbed girders under flexure, and to illustrate its application to the forms of girders most frequently met in practical bridge construction. The plate-girder drawbridge, owing to its frequent use, is one of the most important structures with which the bridge engineer has to deal. Application of the general formula to this case has been made, with the object of giving a simple method of making a better design for the girders and end-lifting machinery for these bridges.

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The writer believes that the determination of the deflection of girders with solid webs is effected best by means of the method of work. The general formula is derived, it will be noticed, in a manner very similar to that commonly used in obtaining the general formula for the deflections of articulate structures.

Let us suppose a beam of any shape in equilibrium under the action of a given loading, and that the following derivation is made under the usual conditions imposed in the development of the fundamental formulas for flexure, and under the supposition that, where the forces producing bending have components in the direction of the length of the beam, the effect of such components in producing distortion may be neglected.

Let M = the bending moment at any section of the beam due to the given loading;

S = the unit stress due to flexure on any fiber of the cross-section, the fiber being distant y from the neutral axis, and

I = the moment of inertia of the cross-section for which the other quantities are taken.

Then, from the fundamental relation for flexure, we have $S = \frac{My}{I}$.

Under the action of flexure, the fibers on one side of the neutral axis of a beam are lengthened, and on the other side they are shortened.

Let dx (an infinitesimal) be a portion of the length of the beam, and λ be the change in length of any fiber distant y from the neutral axis, due to flexure.

From Hooke's Law, we have $\lambda = \frac{SL}{E}$, in general, and for a fiber of a length dx, $\lambda = \frac{S\,dx}{E}$, in which E is the coefficient of elasticity of the material.

Since $S = \frac{My}{I}$,

$$\lambda = \frac{My}{EI}\,dx.$$

Now, simultaneously with the given loading, suppose a force of unity to be applied to the beam at any point in any desired direction. Let m be the bending moment at any section of the beam thereby produced. The stress on any fiber (the same fiber for which λ is taken) of any section due to the assumed load of unity $= \frac{my}{I}$, and the work done by this stress, assuming it to be gradually produced, acting through the distance λ, is equal to $\frac{my}{2I} \times \lambda = \frac{My}{2I} \times \frac{my}{EI} dx = \frac{Mmy^2\,dx}{2EI^2}$.

Letting $\int dA$ represent the area of the entire cross-section, the work done on an infinitesimal portion of the length of the beam $= \frac{Mm}{2EI^2}\left(\int y^2\,dA\right)dx$, and since $\int y^2\,dA = I$, this work $= \frac{Mm\,dx}{2EI}$, and for the internal work throughout the length of the beam due to flexure we have:

$$W = \int_0^l \frac{Mm\,dx}{2EI} \quad \dots\dots\dots\dots (1)$$

Again, let Δ be the deflection, due to the given loading, of the point at which the force of unity is applied, measured along the line of action of the force unity, then the work done by the force of unity gradually applied is:

$$W = \frac{1}{2} \times \Delta = \frac{\Delta}{2} \quad \dots\dots\dots\dots (2)$$

Making the total work of the internal stresses due to flexure (1) equal to the total work of the external forces (2), we have:

$$\frac{\Delta}{2} = \int_0^l \frac{Mm\,dx}{2EI}$$

$$\Delta = \int_0^l \frac{Mm\,dx}{EI}{}^{*} \quad \dots\dots\dots\dots (3)$$

which is the general value for the deflection of any point in a beam.

As an illustration of the general application of this formula, suppose we find the horizontal deflection of the upper corner of a simple I-beam span, loaded at the center with the weight P. Fig. 1 will make the problem more clear.

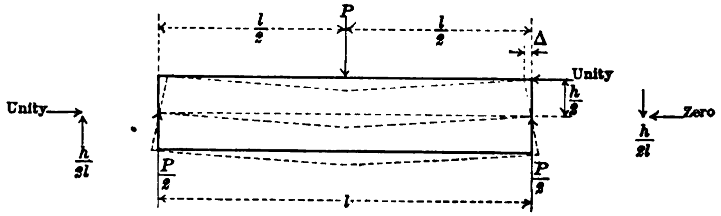

FIG. 1.

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* This formula was first derived by Professor Fraenkel.

Taking each half of the beam separately, and taking the ends of the neutral axis of the beam as the origin of x, we have:

$$\varDelta = \int_0^l \frac{M m\, dx}{E I} = \int_0^{\frac{l}{2}} \frac{M m\, dx}{E I} \text{ for the left half}$$

$$+ \int_0^{\frac{l}{2}} \frac{M m\, dx}{E I} \text{ for the right half,}$$

in which,

$$M = + \frac{P}{2} \times x, \text{ for both right and left halves of the beam,}$$

$$m = + \frac{h}{2l} \times x, \text{ for the left half of the beam,}$$

$$\text{and } m = - \frac{h}{2l} \times x + \frac{h}{2}, \text{ for the right half of the beam.}$$

Substituting these values for M and m in the general equation, we have:

$$\varDelta = \int_0^{\frac{l}{2}} \frac{P h x^2 dx}{4 l E I} - \int_0^{\frac{l}{2}} \frac{P h x^2 dx}{4 l E I} + \int_0^{\frac{l}{2}} \frac{P h x\, dx}{4 E I}$$

$$= \int_0^{\frac{l}{2}} \frac{P h x\, dx}{4 E I} = \frac{P h l^2}{32 E I}.$$

If m make $P = 29\,000$, $l = 360$ ins. and $I = 1\,140$ (inches ^{4th}), this being the value for the moment of inertia of a 20-in. I-beam (192 lbs. per yard), then:

$$\varDelta = \frac{29\,000 \times 20 \times (360)^2}{32 \times 29\,000\,000 \times 1\,140} = \frac{1}{14} \text{ in. nearly.}$$

In the problems of practice it is usually the vertical deflection of some point in a horizontal beam under vertical loading that is desired, The following five problems are deemed sufficient to show the application of the general formula to finding such deflections. The girders in the following problems have four values for the moment of inertia; the resulting expressions for the deflections, however, are of such form that expressions for the value of the deflection for a girder with a greater or less number of values of the moment of inertia can be written by inspection. For girders with inclined flanges values of the moment of inertia can be determined at stated intervals, and these values considered constant for the intervals taken.

Problem No. 1.—Find the vertical deflection at the center of a plate-girder span with three cover-plates, the girder being loaded uniformly throughout its length, l, with a vertical load of w pounds per unit of length. Fig. 2 will make the problem more clear.

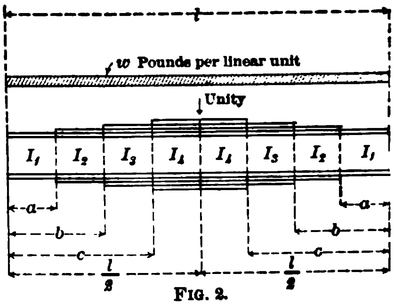

FIG. 2.

As the moment of inertia of the girder has four values, the second part of the general equation,

$$\varDelta = \int_o^l \frac{M m\, d x}{E I} = 2 \int_o^{\frac{l}{2}} \frac{M m\, d x}{E I},$$

will have four parts:

$$\varDelta = \frac{w}{2E} \int_o^a \frac{(l x^2 - x^3)\, d x}{I_1} + \frac{w}{2E} \int_a^b \frac{(l x^2 - x^3)\, d x}{I_2}$$

$$+ \frac{w}{2E} \int_b^c \frac{(l x^2 - x^3)\, d x}{I_2} + \frac{w}{2E} \int_c^{\frac{l}{2}} \frac{(l x^2 - x^3)\, d x}{I_4}$$

$$= \frac{w}{2E} \left\{ \frac{l a^3}{3 I_1} - \frac{a^4}{4 I_1} + l \frac{(b^3 - a^3)}{3 I_2} - \frac{b^4 - a^4}{4 I_2} + l \frac{(c^3 - b^3)}{3 I_3} \right.$$

$$\left. - \frac{c^4 - b^4}{4 I^3} + \frac{l (l^3 - 8 c^3)}{24 I_4} - \frac{l^4 - 16 c^4}{64 I_4} \right\}$$

$$= \frac{5}{384} \frac{w l^4}{E I_4} + \frac{w l}{6 E} \left(\frac{a^3}{I_1} - \frac{a^3}{I_2} + \frac{b^3}{I_2} - \frac{b^3}{I_3} + \frac{c^3}{I_3} - \frac{c^3}{I_4} \right)$$

$$- \frac{w}{8 E} \left(\frac{a^4}{I_1} - \frac{a^4}{I_2} + \frac{b^4}{I_2} - \frac{b^4}{I_3} + \frac{c^4}{I_4} - \frac{c^4}{I_4} \right)$$

which is the expression for the value of the desired deflection.

If $I_1 = I_2 = I_3 = I_4$, that is, if the moment of inertia of the beam be constant, the expression becomes:

$\varDelta = \frac{5}{384} \frac{w l^4}{E I}$, which is the well-known formula for the deflection at the center of a simple beam of constant moment of inertia, under uniform loading.

Problem No. 2.—Find the vertical deflection at the center of a plate-girder span with three cover-plates, due to a vertical load, P, at any point in the span.

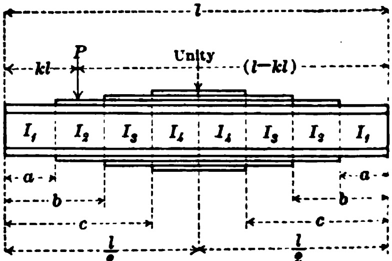

FIG. 3.

The load, P, will be placed on the first cover-plate, and the expression found for the value of the deflection. The expression for the deflection for any desired position of P can then be written by inspection.

$$\begin{aligned}
\Delta &= \int_o^l \frac{M\, m\, d\, x}{E\, I} \\
&= \int_o^a \frac{P\,(1-k)\, x^2\, d\, x}{2\, E\, I_1} + \int_a^{kl} \frac{P\,(1-k)\, x^2\, d\, x}{2\, E\, I_2} \\
&+ \int_k^b \frac{P\, k\,(l\, x - x^2)\; d\, x}{2\, E\, I_2} + \int_b^c \frac{P\, k\,(l\, x - x^2)\, d\, x}{2\, E\, I_3} \\
&+ \int_c^{\frac{l}{2}} \frac{P\, k\,(l\, x - x^2)\, d\, x}{2\, E\, I_4} + \int_o^a \frac{P\, k\, x^2\, d x}{2\, E\, I_1} + \int_a^b \frac{P\, k\, x^2\, d\, x}{2\, E\, I_2} \\
&+ \int_b^c \frac{P\, k\, x^2\, d x}{2\, E\, I_3} + \int_c^{\frac{l}{2}} \frac{P\, k\, x^2\, d\, x}{2\, E\, I_4} \\
&= \frac{P\,(1-k)}{6\, E} \left(\frac{a^3}{I_1} - \frac{a^3}{I_2} + \frac{k^3\, l^3}{I_2}\right) \\
&+ \frac{P\, k}{4\, E} \left(\frac{l\, b^2}{I_2} - \frac{l\, b^2}{I_3} + \frac{l\, c^2}{I_3} - \frac{l\, c^2}{I_4} + \frac{l^3}{4\, I_4} - \frac{l^3\, k^2}{I_2}\right) \\
&- \frac{P\, k}{6\, E} \left(\frac{b^3}{I_2} - \frac{b^3}{I_3} + \frac{c^3}{I_3} - \frac{c^3}{I_4} + \frac{l^3}{8\, I_4} - \frac{k^3\, l^3}{I_2}\right) \\
&+ \frac{P\, k}{6\, E} \left(\frac{a^3}{I_1} - \frac{a^3}{I_2} + \frac{b^3}{I_2} - \frac{b^3}{I_3} + \frac{c^3}{I_3} - \frac{c^3}{I_4} + \frac{l^3}{8\, I_4}\right) \\
&= \frac{P}{6\, E}\left(\frac{a^3}{I_1} - \frac{a^3}{I_2}\right) - \frac{P\, k^3\, l^3}{12\, E\, I_2} \\
&+ \frac{P\, k\, l}{4\, E}\left(\frac{b^2}{I_2} - \frac{b^2}{I_3} + \frac{c^2}{I_3} - \frac{c^2}{I_4}\right) + \frac{P\, k\, l^3}{16\, E\, I_4},
\end{aligned}$$

which is the expression for the value of the desired deflection.

For a load, P, on the second cover-plate, by inspection, can be written:

$$\begin{aligned}
\Delta &= \frac{P}{6\, E} \left(\frac{a^3}{I_1} - \frac{a^3}{I_2} + \frac{b^3}{I_2} - \frac{b^3}{I_3}\right) - \frac{P\, k^3\, l^3}{12\, E\, I_3} \\
&+ \frac{P\, k\, l}{4\, E}\left(\frac{c^2}{I_3} - \frac{c^2}{I_4}\right) + \frac{P\, k\, l^3}{16\; E\, I_4}.
\end{aligned}$$

If we make $I_1 = I_2 = I_3 = I_4$, in either of the above values for Δ, we have:

$\Delta = \frac{P\, k\, l^3}{48\, E\, I}(3 - 4\, k^2)$, and if $k = \frac{1}{2}$, that is, for P in the center of the girder,

$$\Delta = \frac{P\, l^3}{48\, E\, I}.$$

Problem No. 3.—Find the vertical deflection at the loaded point of a plate-girder span with three cover-plates, due to a vertical load, P, at any point in the span.

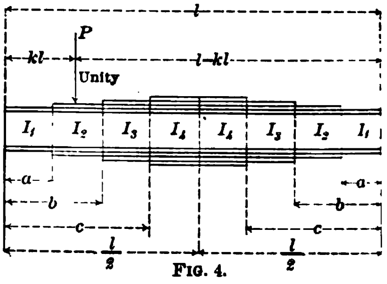

FIG. 4.

P will be placed on the first cover-plate, as in Problem No. 2.

$$\varDelta = \int_o^l \frac{M\,m\,d\,x}{E\,I}$$

$$= \int_o^a \frac{P\,(1-k)^2\,x^2\,d\,x}{E\,I_1} + \int_a^{k\,l} \frac{P\,(1-k)^2\,x^2\,d\,x}{E\,I_2}$$

$$+ \int_{k\,l}^b \frac{P\,k^3\,(l-x)^2\,d\,x}{E\,I_2} + \int_b^c \frac{P\,k^2\,(l-x)^2\,d\,x}{E\,I_3}$$

$$+ \int_c^{\frac{l}{2}} \frac{P\,k^2\,(l-x)^2\,d\,x}{E\,I_4} + \int_o^a \frac{P\,k^2\,x^2\,d\,x}{E\,I_1}$$

$$+ \int_a^b \frac{P\,k^2\,x^2\,d\,x}{E\,I_2} + \int_b^c \frac{P\,k^2\,x^2\,d\,x}{E\,I_3} + \int_c^{\frac{l}{2}} \frac{P\,k^2\,x^2\,d\,x}{E\,I_4}$$

$$= \frac{P\,(1-k)^2}{3\,E}\left(\frac{a^3}{I_1} + \frac{k^3\,l^3}{I_2} - \frac{a^3}{I_2}\right)$$

$$+ \frac{P\,k^2\,l^2}{E}\left(\frac{b}{I_2} - \frac{k\,l}{I_2} + \frac{c}{I_3} - \frac{b}{I_3} + \frac{l}{2\,I_4} - \frac{c}{I_4}\right)$$

$$- \frac{P\,k^2\,l}{E}\left(\frac{b^2}{I_2} - \frac{k^2\,l^2}{I_2} + \frac{c^2}{I_3} - \frac{b^2}{I_3} + \frac{l^2}{4\,I_4} - \frac{c^2}{I_4}\right)$$

$$+ \frac{P\,k^2}{3\,E}\left(\frac{b^3}{I_2} - \frac{k^3\,l^3}{I_2} + \frac{c^3}{I_3} - \frac{b^3}{I_3} + \frac{l^3}{8\,I_4} - \frac{c^3}{I_4}\right)$$

$$+ \frac{P\,k^2}{3\,E}\left(\frac{a^3}{I_1} + \frac{b^3}{I_2} - \frac{a^3}{I_2} + \frac{c^3}{I_3} - \frac{b^3}{I_3} + \frac{l^3}{8\,I_4} - \frac{c^2}{I_4}\right)$$

$$= \frac{P\,l^3\,k^2}{3\,E}\left(\frac{1}{I_4} - \frac{2\,k}{I_2} + \frac{k^2}{I_2}\right) + \frac{P\,(1-2\,k)}{3\,E}\left(\frac{a^3}{I_1} - \frac{a^3}{I_2}\right)$$

$$+ \frac{P\,k^2\,l^2}{E}\left(\frac{b}{I_2} - \frac{b}{I_3} + \frac{c}{I_3} - \frac{c}{I_4}\right)$$

$$- \frac{P\,k^2\,l}{E}\left(\frac{b^2}{I_2} - \frac{b^2}{I_3} + \frac{c^2}{I_3} - \frac{c}{I_4}\right)$$

$$+ \frac{2\,P\,k^2}{3\,E}\left(\frac{a^3}{I_1} - \frac{a^3}{I_2} + \frac{b^3}{I_2} - \frac{b^3}{I_3} + \frac{c^3}{I_4} - \frac{c^3}{I_4}\right),$$

which is the expression for the value of the desired deflection.

If we make $I_1 = I_2 = I_3 = I_4$, then

$\Delta = \frac{P l^3 k^2 (1-k)^2}{3E}$, and, in addition, if we make $k = \frac{1}{2}$, then

$$\Delta = \frac{P l^3}{48 E I}.$$

Problem No. 4.—Find the vertical deflections of the ends of a plate-girder span with three cover-plates, supported at the center, only, and loaded with a uniform vertical load, w, per unit of length.

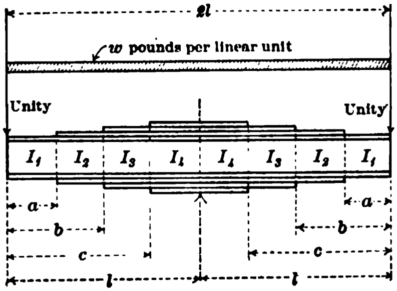

FIG. 5.

$$\Delta = \int_o^l \frac{M m\, d x}{E I}$$

$$= \int_o^a \frac{w x^3\, d x}{2 E I_1} + \int_a^b \frac{w x^3\, d x}{2 E I_2} + \int_b^c \frac{w x^3\, d x}{2 E I_3} + \int_c^l \frac{w x^3\, d x}{2 E I_4}$$

$$= \frac{w}{8 E}\left(\frac{a^4}{I_1} + \frac{b^4}{I_2} - \frac{a^4}{I_2} + \frac{c^4}{I_3} - \frac{b^4}{I_3} + \frac{l^4}{I_4} - \frac{c^4}{I_4}\right)$$

$$= \frac{w l^4}{8 E I_4} + \frac{w}{8 E}\left(\frac{a^4}{I_1} - \frac{a^4}{I_2} + \frac{b^4}{I_2} - \frac{b^4}{I_3} + \frac{c^4}{I_3} - \frac{c^4}{I_4}\right)$$

which is the expression for the value of the desired deflection.

If $I_1 = I_2 = I_3 = I_4$, then,

$$\Delta = \frac{w l^4}{8 E I}.$$

Problem No. 5.—Find the vertical deflection of the ends of a plate-girder span with three cover-plates, supported at the center, only, and loaded at each end with a load, P.

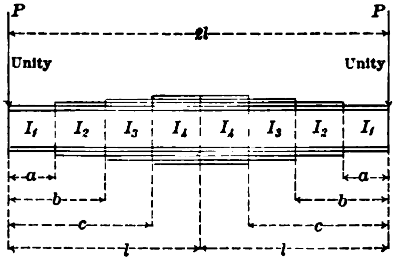

FIG. 6.

$$\Delta = \int_o^l \frac{M m\, d x}{E I}$$

$$= \int_o^a \frac{P x^2\, d x}{E I_1} + \int_a^b \frac{P x^2\, d x}{E I_2} + \int_b^c \frac{P x^2\, d x}{E I_3} + \int_c^l \frac{P x^2\, d x}{E I_4}$$

$$= \frac{P}{3 E}\left(\frac{a^3}{I_1} + \frac{b^3}{I_2} - \frac{a^3}{I_2} + \frac{c^3}{I_3} - \frac{b^3}{I_3} + \frac{l^3}{I_4} - \frac{c^3}{I_4}\right)$$

$$= \frac{P l^3}{3 E I_4} + \frac{P}{3 E}\left(\frac{a^3}{I_1} - \frac{a^3}{I_2} + \frac{b^3}{I_2} - \frac{b^3}{I_3} + \frac{c^3}{I_3} - \frac{c^3}{I_4}\right)$$

which is the expression for the value of the desired deflection.

If $I_1 = I_2 = I_3 = I_4$, then,

$$\Delta = \frac{P l^3}{3 E I}$$

By substituting for Δ, in the above expression, the distance it is desired to raise the end of a plate-girder draw, and solving for P, the uplift necessary to raise the end the desired amount is obtained.

In applying the results of the preceding problems a deduction of 2 or 3 ft. from the over-all lengths of the cover-plates should be made, for the reason that enough rivets to fully develop the value of a cover-plate to resist stress are not generally contained in a less distance than the first 2 or 3 ft. at the end of the cover-plate.

By the aid of the results of Problems Nos. 4 and 5, the reactions for center-bearing plate-girder draw spans, with equal arms under uniform loading, can be obtained.

Let $R_1 = R_3$ be the reactions at the ends of a two-span plate-girder with three cover-plates. From the result of Problem No. 5, we have, for the vertical motion, Δ, due to a force, $R_1 = R_3$, at the ends, the following:

$$\Delta = \frac{R_1 l^3}{3 E I_4} + \frac{R_1}{3 E}\left(\frac{a^3}{I_1} - \frac{a^3}{I_2} + \frac{b^3}{I_2} - \frac{b^3}{I_3} + \frac{c^3}{I_3} - \frac{c^3}{I_4}\right)$$

If, at the same time, we make the value for Δ given by the result of Problem No. 4 equal to the value for Δ above, and solve the equation for R_1, we have:

$$R_1 = R_3 = \frac{\dfrac{w l^4}{8 I_3} + \dfrac{w}{8}\left(\dfrac{a^4}{I_1} - \dfrac{a^4}{I_2} + \dfrac{b^4}{I_2} - \dfrac{b^4}{I_3} + \dfrac{c^4}{I_3} - \dfrac{c^4}{I_4}\right)}{\dfrac{l^3}{3 I_4} + \dfrac{1}{3}\left(\dfrac{a^3}{I_1} - \dfrac{a^3}{I_2} + \dfrac{b^3}{I_2} - \dfrac{b^3}{I_3} + \dfrac{c^3}{I_3} - \dfrac{c^3}{I_4}\right)}$$

$$= \frac{3 w}{8} \; \frac{\dfrac{l^4}{I_4} + \dfrac{a^4}{I_1} - \dfrac{a^4}{I_2} + \dfrac{b^4}{I_2} - \dfrac{b^4}{I_3} + \dfrac{c^4}{I_3} - \dfrac{c^4}{I_4}}{\dfrac{l^3}{I_4} + \dfrac{a^3}{I_1} - \dfrac{a^3}{I_2} + \dfrac{b^3}{I_2} - \dfrac{b^3}{I_3} + \dfrac{c^3}{I_3} - \dfrac{c^3}{I_4}}$$

which is the expression for the value of the end reactions for a plate-girder of two equal spans having four values for the moment of inertia, and loaded uniformly throughout its length by w pounds per unit of length.

If $I_1 = I_2 = I_3 = I_4$, then $R_1 = R_3 = \frac{3}{8} w l$.

It would not be a difficult matter to derive values for the reactions for a more general case of loading and span lengths; but the ordinary plate-girder draw has equal arms, and the only place, under the general practice in designing, where it is necessary to consider the effect of continuous loading is near and over the center support. The maximum values for shear and moment at the center support are given under conditions closely approximating continuous uniform load, and this is the problem we have solved.

In order to see how much the ordinary method (using a constant moment of inertia) of computing the moments over the center supports of plate-girder draws differs from this more exact method, the comparison will be made for two widely different cases.

Case I.—A very light, single-track, center-bearing, plate-girder draw, 72⅛ ins. deep, from out to out of flange-angles.

			Length over all.		Effective length.
1 web plate,	72 × ⅜	ins.	138 ft.	and	136 ft.
4 flange-angles,	5 × 5	"	138 "	"	136 "
(55 lbs. per yard.)					
2 cover-plates,	12 × ⅝	"	98 "	"	96 "
2 " "	12 × ⅝	"	22 "	"	20 "
2 " "	12 × ⅝	"	10 "	"	8 "

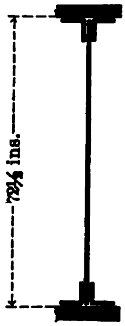

FIG. 7.

$I_1 =$ 38 284 ins.^{4} = 1.85 ft.^{4} and $a = 20$ ft.

$I_2 =$ 58 335 " = 2.81 " $b = 58$ "

$I_3 =$ 79 081 " = 3.81 " $c = 64$ "

$I_4 =$ 100 526 " = 4.85 " $l = 68$ "

$$\frac{a^3}{I_1} = 4\,324.3,\ \frac{a^3}{I_2} = 2\,847.0,\ \frac{a^4}{I_1} = 8\,648.6,\ \frac{a^4}{I_2} = 5\,694.0,$$

$$\frac{b^3}{I_2} = 69\,434.9,\ \frac{f^3}{I_3} = 51\,210.5,\ \frac{b^4}{I_2} = 4\,027\,206.3,\ \frac{b^4}{I_3} = 2\,970\,209.0,$$

$$\frac{c^3}{I_3} = 68\,804.2,\ \frac{c^3}{I_4} = 54\,050.3,\ \frac{c^4}{I_3} = 4\,403\,468.8,\ \frac{c^4}{I_4} = 3\,459\,219.8,$$

$$\frac{l^3}{I_4} = 64\,831.3 \qquad \frac{l^4}{I_4} = 4\,408\,531.1,$$

$$+ = 207\,394.7,\ - = 108\,107.8,\ + = 12\,847\,854.8,\ - = 6\,435\,122.8,$$

$$R_1 = \frac{3}{8}\,w\,\frac{\frac{l^4}{I_4} + \frac{a^4}{I_1} - \frac{a^4}{I_2} + \frac{b^4}{I_2} - \frac{b^4}{I_3} + \frac{c^4}{I_3} - \frac{c^4}{I_4}}{\frac{l^3}{I_4} + \frac{a^3}{I_1} - \frac{a^3}{I_3} + \frac{b^3}{I_3} - \frac{b^4}{I_3} + \frac{c^4}{I_3} - \frac{c^4}{I_4}}$$

$$= \frac{3}{8}\,w\,\frac{12\,847\,854.8 - 6\,435\,132.8}{207\,394.7 - 108\,107.8} = \frac{3}{8}\,w\,64.59 = 24.22\,w.$$

The moment over the center support for this case is:

$M = 68\ w\ (24.22 - 34.00) = -\ 665.04\ w$ foot-pounds.

The moment over the center support for constant moment of inertia is:

$$M = -\frac{1}{8} w\ l^2 = -\ 578\ w \text{ foot-pounds,}$$

which shows that this more exact method gives a moment over the center support for this case 15% greater than the usual method.

Case II.—A very heavy, double-track, center-bearing, plate-girder draw, 101½ ins. deep, from out to out of flange angles.

		Length over all.		Effective length.
1 web plate,	101 × $\frac{11}{16}$ ins.,	159 ft.	and	156 ft.
4 side flange-plates,	18 × $\frac{3}{4}$ "	159 "	"	156 "
4 flange angles, (125 lbs. per yard.)	8 × 6 "	159 "	"	156 "
2 cover-plates,	20 × $\frac{3}{4}$ "	159 "	"	156 "
2 " "	20 × $\frac{3}{4}$ "	84 "	"	82 "
2 " "	20 × $\frac{3}{4}$ "	24 "	"	22 "
2 " "	20 × $\frac{3}{4}$ "	16 "	"	14 "

$I_1 = 353\ 750$ ins.^{4} $= 17.06$ ft.^{4} and $a = 37$ ft.

$I_2 = 434\ 500$ " $= 20.96$ " " $b = 67$ "

$I_3 = 517\ 600$ " $= 24.96$ " " $c = 71$ "

$I_4 = 603\ 100$ " $= 29.08$ " " $l = 78$ "

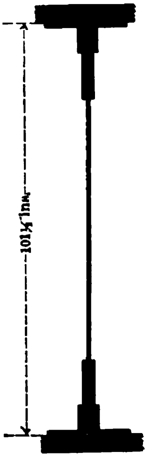

FIG. 8.

$$\begin{array}{llll}
\frac{a^3}{I_1} = 2\ 969.1, & \frac{a^3}{I_2} = 2\ 416.7, & \frac{a^4}{I_1} = 109\ 857.3, & \frac{a^4}{I_2} = 89\ 416.1, \\
\frac{b^3}{I_2} = 14\ 349.4, & \frac{b^3}{I_3} = 12\ 049.9, & \frac{b^4}{I_2} = 961\ 408.5, & \frac{b^4}{I_3} = 807\ 336.6, \\
\frac{c^3}{I_3} = 14\ 339.3, & \frac{c^3}{I_4} = 12\ 307.8, & \frac{c^4}{I_3} = 1\ 018\ 096.2, & \frac{c^4}{I_4} = 873\ 854.2, \\
\frac{l^3}{I_4} = 16\ 318.8, & & \frac{l^4}{I_4} = 1\ 272\ 869.9 & \\
\hline
+ = 47\ 976.6 & - = 26\ 774.4 & + = 3\ 362\ 231.9 & - = 1\ 770\ 606.9,
\end{array}$$

$$R_1 = \frac{3}{8} w \frac{3\ 362\ 231.9 - 1\ 770\ 606.9}{47\ 976.6 - 26\ 774.4} = \frac{3}{8} w\ 75.07 = 28.15\ w.$$

The moment over the center support, for this case, is:

$M = 78\ w\ (28.15 - 39.00) = -\ 846.30\ w$ foot-pounds.

The moment over the center support, for constant moment of inertia, is:

$$M = -\frac{1}{8}\, w\, l^2 = 760.5\ w \text{ foot-pounds.}$$

Which shows that this more exact method gives a moment over the center support for this case 11% greater than the usual method.

The two plate-girder drawbridges selected for investigation may be said to represent fairly the results obtained by the method commonly used in designing such structures. In view of the results of the investigation for these two cases, it is fair to assume that many center-bearing plate-girder drawbridges are stressed considerably higher, for a short distance over the center support, than their designers intended they should be. This condition of affairs, it is believed, is quite generally known, but, as far as the writer knows, has not influenced designers. The additional material required for a more correct design is a very small percentage of the whole weight, and, considering the increased strength it would give, the addition should always be made.

The objection may be made that it is hardly necessary to go to any great refinement in designing plate-girder drawbridges, as it is not certain that the end machinery will act as designed, and, further, even though the condition of the supports be as assumed, until account is taken of the effect of the shearing stresses in producing distortion, the true reactions cannot be obtained. The fact that the end supports may be out of their proper position, and in such a manner as to cause increased bending moments over the center support, is an argument in favor of the most refined methods in designing the structure. It is not customary to consider the effect of the shearing stresses in producing distortion, in designing plate-girder drawbridges; the method used in investigating Case I and Case II is simply a more refined application of the usual method (which considers only flexural stresses). In order to determine the effect of the shearing stresses in producing deflection, the following investigation is made:

Let us take any portion of a beam in equilibrium under the action of transverse loading, as shown in Fig. 9. If P be the resultant in position, direction and amount of all the forces to the right of the section $m\ n$, then it is clear that

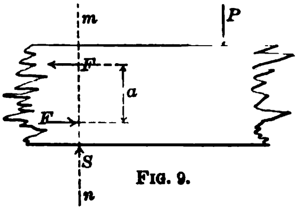

FIG. 9.

the portion of the beam under consideration would be kept in equilibrium by the couple, Fa, and the shear, S.

In general, no matter what may be the actual distribution of the stresses on any section of a beam under a given loading, these stresses may be resolved into an equivalent couple and shear. The effect of the couple in doing work has been determined in accordance with the common theory of flexure. Going back to (1), and rewriting the expression for the work of the internal stresses, we have

$$w = \left(\int_o^l \frac{Mm\,dx}{2\,EI} \text{ for the work of the flexural stresses}\right)$$
$$+\left(\int_o^l \frac{Ss\,dx}{2\,E_s\,A} \text{ for the work of the shearing stresses}\right).$$

To derive the expression for the work done by the shearing stresses:

Let S = shear at any point, due to the given loading;

s = shear at any point, due to a load of unity at the point where deflection is desired;

A = total area of the cross-section;

E_s = coefficient of elasticity for shear;

and let $d\,x$ be an infinitesimal portion of the length of the beam; that is, let it be considered as the distance between two consecutive sections of the beam.

Then, under the action of the shearing stress, S, the two consecutive sections will have a relative motion of $\frac{S\,d\,x}{A\,E_s}$, if we assume that the shearing stress is distributed uniformly over the cross-section.

Now, as for the flexural stresses, we will suppose the force of unity to be applied gradually; then the work done by the shearing stress, on an elementary portion of the beam, due to the force of unity, is $\frac{S\,d\,x}{A\,E_s} \times \frac{s}{2}$, and, over the entire beam, the work is $\int_o^l \frac{S\,s\,d\,x}{2\,E_s\,A}$.

Making the expressions for the external and internal work equal, we have:

$$\frac{\Delta}{2} = \int_o^l \frac{M\,m\,d\,x}{2\,E\,I} + \int_o^l \frac{S\,s\,d\,x}{2\,E_s\,A}, \text{ and}$$

$$\Delta = \int_o^l \frac{M\,m\,d\,x}{E\,I} + \int_o^l \frac{S\,s\,d\,x}{E_s\,A}.$$

The shearing stress is not distributed uniformly over the cross-section, and hence the term for the work of the shearing stress should be modified by a coefficient. The value of this coefficient for a rectangular section is very readily shown to be $\frac{6}{5}$.

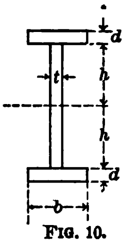

FIG. 10.

For a section, as shown in Fig. 10, which is a close enough approximation to plate-girder cross-sections, for all practical purposes, the work done by the shearing stresses due to unity, taking the intensity of the vertical shear as equal to the intensity of the horizontal shear at all points of the cross-section, on two flanges

$$= \frac{b\,[8\,(h+d)^5 - 15\,(h+d)^4\,h + 10\,(h+d)^2\,h^3 - 3\,h^5]}{30\,I^2} \int_o^l \frac{S\,s\,d\,x}{E_s}$$

and on the web

$$= \frac{30\,b^2\,d^2\,\frac{h}{t}\left(h+\frac{d}{2}\right)^2 + 20\,b\,d\,h^3\left(h+\frac{d}{2}\right) + 4\,h^5\,t}{30\,I^2}$$

$$\int_o^l \frac{S\,s\,d\,x}{E_s}$$

The total work on the entire cross-section is the sum of these, and

$$= \frac{\begin{gathered}8\,b\,(h+d)^5 - 15\,b\,k\,(h+d)^4 + 10\,b\,h^3\,(h+d)^2 \\ -3\,b\,h^5 + 30\,b^2 d^2\,\frac{h}{t}\left(h+\frac{d}{2}\right)^2 \\ +\,20\,b\,d\,h^3\left(h+\frac{d}{2}\right) + 4\,h^5\,t\end{gathered}}{30\,I^2} \int_o^l \frac{S\,s\,d\,x}{E_s}$$

This expression is of such an involved nature that a simple inspection gives very little information as to the relative value of the work on the flanges and web to that of the work on the entire cross-section. For the purpose of getting a definite idea of this relation, and, at the same time, for reinvestigating the plate-girders of Case I and Case II, approximate sections for the end and center of each of these girders will be assumed.

Case I.

Approximate end-section:	Approximate center-section:
$b = 12$ ins.	$b = 12$ ins.
$d = 1$ "	$d = 2$ "
$h = 36$ "	$h = 36$ "
$t = \frac{3}{8}$ "	$t = \frac{3}{8}$ "
Work on flanges = 0.0003	Work on flanges = 0.0008
Work on web = 0.9997	Work on web = 0.9992

Case II.

Approximate end-section:	Approximate center-section:
$b = 20$ ins.	$b = 20$ ins.
$d = 2$ "	$d = 4$ "
$h = 50$ "	$h = 50$ "
$t = \frac{3}{4}$ "	$t = \frac{3}{4}$ "
Work on flanges = 0.0006	Work on flanges = 0.0013
Work on web = 0.9994	Work on web = 0.9987

From this it is seen that the amount of work done on the flanges is a very small part of the total work on the cross-section. A similar investigation on a section more closely approximating the actual cross-section of a plate-girder, as shown in Fig. 11, would show a considerably larger amount of work for the flanges; but it would still be very small. Therefore, in investigating the effect of shear in producing distortion on plate-girders it will be very nearly correct to assume that the web alone resists all the shearing stresses. This assumption would give deflections a little too great, as the flanges of a plate-girder do take a small part of the shear—for a plate-girder such as that in Case II the vertical flange plates and the vertical legs of the flange-angles take considerable shear; however, in the investigation to follow, the effect of the unequal distribution of the shear over the web will be neglected.

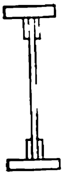

FIG. 11.

This assumption produces an error opposite to and generally greater than the first assumption, so that the resulting deflections determined under these assumptions will be very nearly correct, but probably a trifle too small.

The general equation for the deflection of a plate-girder of varying cross-section now becomes

$$\varDelta = \int_o^l \frac{M\,m\,d\,x}{E\,I} + \int_o^l \frac{S\,s\,d\,x}{E_s\,A_w},$$ in which A_w = area of web.

Making $E_s = \frac{2}{5} E$, the deflection

$$\varDelta = \int_o^l \frac{M\,m\,d\,x}{E\,I} + \frac{5}{2}\int_o^l \frac{S\,s\,d\,x}{E\,A_w}.$$

From this the expression for the value of the deflection for Problem No. 4 becomes

$$\varDelta = \frac{w}{8\,E}\left(\frac{l^4}{I_4} + \frac{a^4}{I_1} - \frac{a^4}{I_2} + \frac{b^4}{I_2} - \frac{b^4}{I_3} + \frac{c^4}{I_3} - \frac{c^4}{I_4}\right) + \frac{5}{4}\,\frac{w\,l^2}{E\,A_w};$$

and for Problem No. 5 it becomes

$$\varDelta = \frac{P}{3\,E}\left(\frac{l^3}{I_4} + \frac{a^3}{I_1} - \frac{a^3}{I_2} + \frac{b^3}{I_2} - \frac{b^3}{I_3} + \frac{c^3}{I_3} - \frac{c^3}{I_4}\right) + \frac{5}{2}\,\frac{w\,l^2}{E\,A_w}$$

The expression for the value of the end reactions for a plate-girder of two equal spans, the girder having four values of *I*, and loaded uniformly throughout its length by *w* pounds per unit of length, is:

$$R_1 = R_3$$

$$= \frac{3}{8}\,w\,\frac{\left(\frac{l}{I_4} + \frac{a^4}{I_1} - \frac{a^4}{I_2} + \frac{b^4}{I_2} - \frac{b^4}{I_3} + \frac{c^4}{I_3} - \frac{c^4}{I_4}\right) + \frac{10\,l^2}{A_w}}{\left(\frac{l^3}{I^4} + \frac{a^3}{I_1} - \frac{a^3}{I_2} + \frac{b^4}{I_2} - \frac{b^3}{I_3} + \frac{c^3}{I_3} - \frac{c^3}{I_4}\right) + \frac{15\,l}{A_w}}.$$

Using this expression in investigating Case I and Case II:

For Case I:

$$R = \frac{3}{8}\,w\,\frac{6\,412\,732 + 246\,613}{99\,287 + 2\,720} = \frac{3}{8}\,w \times 65.28 = 24.48\ w;$$

and the moment over the center support,

$$M = 68\ w\ (24.48 - 34.00) = -\ 647.36\ w \text{ foot-pounds.}$$

This moment is only 2.6% less than that found by the first investigation for Case I.

For Case II:

$$R = \frac{3}{8}\,w\,\frac{1\,591\,625 + 126\,165}{21\,202 + 1\,213} = \frac{3}{8}\,w \times 76.64 = 28.74\ w;$$

and the moment over the center support,

$$M = 78\ w\ (28.74 - 39.00) = -\ 800.28\ w \text{ foot-pounds.}$$

This moment is 5.5% less than that found by the first investigation for Case II.

The result of this reinvestigation for Case I and Case II shows: For the shorter and lighter draw-span, that the deflection of the end of the span, due to the shearing stresses caused by uniform loading, is about 4% of that due to the flexural stresses from the same cause; that the deflection of the end of the span due to the shear caused by a load at the end is about 3% of that due to the flexural stresses from the same cause; and that the calculated moment over the center support, obtained by a consideration of the flexural stresses alone, is about 2.6% greater than that obtained by taking into account the effect of the shearing stresses.

For the longer and heavier draw-span, the consideration of the effect of the shearing stresses shows differences about twice as great, in each instance, as was shown for the shorter and lighter structure.

That the effect of the shearing stresses should be greatest in the long girder, does not seem to be in accord with the fact that, for a beam of constant cross-section, the relative effect of the shearing stresses is less the longer the span; an inspection of all the elements of the problem shows that the much larger moment of inertia and the relatively less area in the web of the long girder are more than sufficient to overcome the effect of its greater length. In view of the results of this investigation it would seem to be necessary to consider the effect of the shearing stresses, in modifying the effect of the flexural stresses in designing, only for very deep girders subject to very heavy loads. The amount of labor required for a proper consideration of the shearing stresses is very small, so that whenever great accuracy is required they should always be considered.

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PAPERS AND DISCUSSIONS.

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THE PANAMA CANAL.

Discussion.*

By Messrs. M. Meigs, Theodore Paschke, C. L. Harrison, P. Bunau-Varilla and George S. Morison.

M. Meigs, M. Am. Soc. C. E. (by letter).—This extremely interesting paper on the Panama Canal and its problems will appeal strongly to all engineers, and no doubt awaken wide discussion. So far, the writer has not been able, from the discussion on the papers on the Isthmian Canal problem he has seen, to discover whether the Chagres is a mountain torrent of clear water, rolling stone, gravel and sand along its bed, or a silt-bearing stream, charged with mud as well as sand. In his opinion, there is a vast difference between the two, not alone as affecting the cost of the up-keep of the canal, but also the practicability of the scheme, now little talked of, for a sea-level canal, and as related to the problem of the Bohio Dam. Mr. Meigs.

The writer has had twenty years' experience on a canal, 7½ miles long and 250 to 350 ft. wide, on the Mississippi River, at Keokuk, Iowa. This canal receives the, at times, muddy water of the river, necessary to feed it and to provide for lockage; and, in addition, two small creeks and a few short watercourses empty directly into the canal. The rainfall in this latitude is only 40 ins., as against 200 ins., or thereabout, on the Isthmus, and yet it requires the almost constant attention of a dredge to keep the channel open for navigation.

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* This discussion (of the paper by George S. Morison, Past-President, Am. Soc. C. E., printed in *Proceedings* for January, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.

Communications on this subject received prior to April 24th, 1903, will be published subsequently.

Mr. Meigs. In the twenty years of the writer's connection with the canal, 1 600 000 cu. yds. of mud, sand and gravel have been removed from the canal prism in a length of not more than 5 miles; two deep pools at the lower ends of reaches of the canal not yet having shoaled sufficiently to require dredging, and aggregating about 2 miles of the 7½ miles of canal.

On several occasions a single storm, lasting not 24 hours, has thrown enough material into the canal to keep a large Osgood dredge at work for a month removing it, working night and day 16 out of the 24 hours. It would seem that any sea-level plan would be negatived by the dredging requirements necessary to keep the channel open. With a 32-ft. boat it would require but a small rush of water from some side stream to cause a stoppage of navigation. The sea-level canal, necessarily, would be the recipient of all the débris washed down the tributary streams. A large rock rolled into the channel would cause the sinking of the first heavy-draft steamer that came along, and, in fact, the delays and expense would be interminable.

At the Keokuk Canal a sluice in the upper level allows of a short tow for the dredge tender, as the sluice is used to wash the dredged material into the river by opening certain gates. At Panama there would seem to be no method of getting rid of the material dredged except by elevating it to the sides of the canal, or by towing it out to sea. Either of these methods would be slow and very costly. Even if there is clear water at all times, there will be, for a sea-level canal, constant trouble at the mouth of every creek and river. It is true that dams along the course of these streams would retain a portion of the débris for a time, but they would soon fill up, and dredging would have to be the result in the end. This has happened already to the Keokuk Canal. From a dredging standpoint, the sea-level canal looks like an impossibility.

All this is changed in the admirable high-level reservoir and lock scheme worked out by the Canal Commission and Mr. Morison. Whether bearing silt, or only sand and gravel, Lake Bohio will perform a most valuable office in providing a settling ground for the water used in the canal. No doubt the greater part of the sediment will remain in the lake, and the necessity for constant dredging in the canal prism will be avoided for a long time.

Mr. Morison's design for a temporary dam seems to the writer to be sufficiently good for the permanent structure. There seems to be no reason why iron should not be adopted as the material for permanent and high dams. It should be remembered that such a dam as sketched in Mr. Morison's paper on "The Bohio Dam" can be made absolutely tight. The construction would afford a view of the lower side of the dam at all times, and all leakage could be detected and stopped at any time. If kept painted, it would rust only on the upper side, and the rate of deterioration would be very small. Wrecks of vessels thirty years and more under water, on the upper part of the Mississippi River, show in their ironwork but little loss from rust. A brown scale is formed on the surface, looking like brown varnish, and this seems to protect the iron. Mr. Meigs.

If the dam were built early in the progress of the work, would it not, by means of the lake, give a cheap means of transporting the spoil from the prism of the canal? That spoil, dumped from barges above the dam, would, in the course of the construction of the canal, fill the valley, and would make a dam that would be absolutely beyond suspicion, and at little comparative expense where the work is almost entirely a cut As for percolation, it would cut that off entirely, for it seems to the writer that the percolation has been more dreaded than there is any occasion for. If Mr. Morison's iron dam were merely set upon a broad sheet of concrete extending some distance above the dam, and the bearing under the dam were fortified by driving plenty of round piling to give a firm foundation and also to consolidate the soil; if this dam were built between abutments of stone, with an earth embankment beginning at the point where it would be possible to reach bed-rock with caissons, thus securing a tight connection with the bottom of the geological valley; and if, under the sheet of concrete, several rows of sheet-piles, preferably of iron, like the dam, were driven across the valley from one abutment to the other, the writer thinks that the foundation of the dam, and the percolation beneath it, would be sufficiently guarded, without having to go to the unparalleled depth for foundations, which, in the minds of many engineers, seems to be necessary. There are, in India, tanks, as they are called, which are formed by earth dams of heights equal to the Bohio Dam, and they have stood for centuries. Some of these dams, it is said, were built by sluicing material from the adjoining hills in troughs fed by the mountain streams in the vicinity. It is not likely that the people who built those dams went into refinements about bed-rock foundations.

On the section marked *B**, on the map of dam sites, it would seem, from rough calculation, that a dam might be constructed consisting of 350 ft. of embankment at each end and a connecting section of iron, not more than 550 ft. long. This iron dam would be about 100 ft. high, but what better or more trusty material can be found? The calculation of the forces entering into the problem are simple, too; much simpler than in the case of a bridge, and the material would be used economically. The work could be done in a temperate climate—all but the setting up—and, during erection, the river could be allowed to flow between the bents until the final moment of closure. It is this feature—of doing most of the work in high-class shops and shipping it out ready to erect—that most commends itself. Finally, if this

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* The "Bohio Dam." *Transactions*, Am. Soc. C. E., Vol. XLVII, p. 239.

Mr. Meigs. dam were erected early, and, on being tested, were found wanting, it could be replaced with some other structure, without interfering with the opening of the canal. The writer cannot help thinking that Mr. Morison's estimate for the earth dam is too low, though if built, it would certainly solve the problem.

Mr. Paschke. THEODORE PASCHKE, M. Am. Soc. C. E.—Mr. Morison's plan for a tide-level canal, as outlined in his excellent paper, is a very attractive one, and must appeal to all engineers and others who take any interest whatever in the question.

Heretofore, the control of the Chagres River, has been the great stumbling block in the way of a sea-level canal. The International Technical Commission, under the leadership of the genial de Lesseps, in declaring for a sea-level canal at Panama, certainly showed no lack of boldness in conception or assertion. But "'twas easier said than done."

As far as the writer is aware, no tangible, practical plan for the control of the Chagres, beyond a proposition to dam the river at Alhajuela and divert its waters, from the reservoir thus formed, through a new channel to the sea at a sufficient distance from the canal, had been evolved. The managers of the enterprise at Paris evidently depended upon the many eminent engineers who were sent out to the Isthmus to solve the problem in all its working details on the spot.

These, in turn, for the most part unused to accommodating themselves to the new and strange surroundings, unnerved by the debilitating influence of the climate, and over-awed by the apparent impenetrability of a tropical jungle and the magnitude of the problem before them, threw up their hands in despair and either fell victims to the pernicious fevers, or, if survivors, were subdued in spirit.

The rest of the story—the prodigality of the management, the subsequent exhaustion of funds and the final abandonment of the sea-level canal in favor of a lock canal—is a matter of history, and needs no further mention.

This grand failure to make good the decree of the International Technical Commission has been like a ban upon the project of a sea-level canal with the majority of engineers ever since. Therefore, it is refreshing and reassuring to have an engineer of Mr. Morison's standing come out with a proposition for a tide-level canal on entirely new lines; on lines of such bold simplicity that at once they not only assure the feasibility of the plan, but call forth an unstinted admiration for the author's sagacity, and give evidence of his fitness to deal with such problems.

The plan, as outlined in the paper, seems to have been left, probably intentionally, in a somewhat incomplete form, so as to invite criticism and discussion. As far as the plan is outlined by the author, the speaker has no criticism to offer, but only desires to point out certain natural conditions and features in connection therewith, which, when properly adjusted, may tend to assist in making those outlines a little more definite. Mr. Paschke.

Mr. Morison, by calculations based upon reliable data, regarding the discharge of the Chagres River, has drawn the conclusion that it would require a canal 400 ft. in width to accommodate the maximum ordinary flood discharge without injury to the canal; with the reservation that this width might prove inadequate for a repetition of a flood like that of 1879. On this the speaker has only one comment to make, and that is: Why draw the limit at a width of 400 ft.? Having gone that far, it would be as well to go a little farther and obtain an adequate factor of safety. However, the speaker quite agrees with Mr. Morison that the construction of a dam at Alhajuela would be a more rational measure, not only for the control of the Chagres waters, but for another reason to be mentioned directly.

Mr. Morison has given the average elevation of the bed of the Chagres at Gamboa as 45 ft. above tide level, and the elevation of the bottom of the canal as 35 ft. below. This makes a fall of 80 ft. from the bed of the river to the bottom of the canal. A discharge of 70 000 cu. ft. per second over a precipice 80 ft. high almost makes one think of Niagara. It is plain that something must be provided to meet this condition. Some sort of a receiving basin or pool, of adequate dimensions, will have to be excavated, to bring the waters to rest, so that they may enter the canal quietly.

The contemplation of this feature naturally leads to another question: What becomes of the detritus and the sediment brought down by the river during floods? How is that to be taken care of?

It is to be regretted that so little consideration has been given this subject by the various commissions and engineers who, of late, have reported and written upon the problem of an Isthmian Canal. This subject is a very important feature in any proposition for the control of the Chagres River, and, if ignored in the formulation of the plans, will force itself, sooner or later, upon the operators of the canal when completed. It would be well to have some systematic observations upon this subject made during the coming rainy season, to ascertain the amount and character of the sediment carried in suspension by the Chagres River during floods.

The topography of Central America has a character peculiar to itself. It is volcanic, throughout. The underlying rocks are covered with deep layers of volcanic ashes or dust, of varying fineness, giving the country, in its principal features, a soft, undulating profile, which is only pierced here and there by groups of volcanic cones, for the most part now silent, but bearing witness of a former activity.

The accentuations which occur in the landscape are principally due to the action of water. This action of furrowing the surface

Mr. Paschke. and deepening and widening the cañons or barrancos down to bedrock is still going on, and may be observed in any of the mountain streams during a flood. An inspection of the steep banks will reveal, like an open book, the character and thickness of the various layers of volcanic dust or ashes, and give in unmistakable language an account of the magnitude of the process necessary for the formation of these covering strata. With the exception of a few isolated cases, very little evidence has come under the speaker's observation to show that in the latter part of the eruptive period of that country, flows of liquid rock or lava have taken place. It seems that during this period, the eruptive material has only been ashes or dust, or these materials mixed with water as liquid mud. This latter observation has been verified by the many traditions among the aboriginal inhabitants relating to water- or mud-throwing volcanoes.

Most of this volcanic material has attained a certain consistency, a certain degree of hardness or cohesiveness, which allows it to stand, when pierced by an excavation like that for a railroad cut, with a slope approaching very nearly to the vertical. In fact, the speaker's experience has been, that the nearer to the vertical the faces of these slopes are kept, the better they stand, provided the surface drainage above is properly taken care of. The reason for this is, that, in the first place, it is a characteristic of most of this volcanic material, that its surface, when exposed to atmospheric influence, hardens slightly, giving it a crust-like protection; secondly, the nearly vertical face is not exposed to the action of the tropical rain torrents to such an extent as a face at the ordinary and customary slope of 1 to 1. However, on the other hand, all this material yields easily to erosion by flowing water. This may be traced out readily in any of the mountain streams of that country.

When exposed to the action of flowing water this material is reduced quickly to its original form, the coarser particles, in the form of sand, are carried down stream, a varying distance, but the finer particles, which in some cases form by far the greater portion of the mass, are carried off in complete suspension, in which condition they are held for a long time. Even when the speed of the flow has slackened or has come to a practical standstill, as in the case of a stream emptying into a lake or reservoir, the process of deposit is slow.

All accounts and descriptions of the physical character of the Isthmus of Panama agree that it is volcanic, and the speaker's observations, made while crossing the Isthmus on two different occasions, confirm the view that the general description of the covering strata of Central America, just given, applies also to the Isthmus, possibly in a somewhat less marked degree. A deduction that the Chagres River is no exception, in this respect, to any of the larger Central American rivers which have come under the speaker's close observa-

Mr. Paschke.

tion, would seem to be entirely logical. An inspection of the river beds of that region at any appreciable elevation above sea level, where the flood waters are entirely confined by the banks, will fail to reveal evidences of the quantity of fine silt carried by their flood waters, for the reason that nothing but portions of the coarser particles—the sand and gravel—remain, the finer silt particles are carried down stream in suspension, and, if the flood is not large enough to overflow the lower banks, are carried to the sea.

Returning now to the discussion of the tide-level canal, it is to be observed that the proposed dam at Alhajuela will serve most admirably the two-fold purpose of controlling the flood waters and detritus brought down from the upper valley; but, even so, one is confronted by the fact that there exists the tendency to silt up this reservoir in time. And if the control of the Chagres waters depends upon the unimpaired capacity of this reservoir, then its gradual silting up is a serious condition, and must be reckoned with by the designers of the canal works.

From Alhajuela, at the foot of its dam, to Gamboa, where the river strikes the canal, is about 7 miles, according to Mr. Morison's statement. Some tributary streams empty their waters into the Chagres here, and their united waters, by the time they arrive at the canal, will be highly charged with sediment. The proposed receiving basin at this point, mentioned before, can be made a settling basin by enlarging it and deepening it somewhat below the bed of the canal. By periodical dredging, this basin can be kept clean, and in this way the water entering the canal will be freed of all coarser sediment. How much of the finer particles of silt would be deposited in the canal, under the varying conditions of current speed, will be, at this time, for want of reliable data on this subject, purely a matter of conjecture. If the speaker were to venture an opinion, it would be, that the quantity deposited under these conditions would be proportionately insignificant, and insufficient to cause doubt as to the feasibility of the plan.

Again, if the arguments just advanced are applied to the plans for a lock canal, and to Bohio Lake in particular, the conclusion is evident that something must be done to prevent the lake from silting up. Two ways suggest themselves, which, singly or in combination, would effect a partial remedy. One is that the dam proposed to be built at Alhajuela for the tide-level canal would do the same service for the lock canal. The other would be to reserve the part of the lake from Alhajuela to Gamboa for a settling basin, to be kept clean by periodical dredging.

In both cases, though, we are confronted with the ever-existing danger of the final silting up of the lake by the finer material which cannot be precipitated in the settling basin; however, with the ameliorating condition, that the process will be an exceedingly slow one.

Mr. Paschke. To return to the subject of a sea-level canal, it would be interesting indeed if some of the engineers who are members of the Isthmian Canal Commission could or would give some idea regarding the feasibility, and probable cost, of the so-called diversion of the Chagres River from the Alhajuela Reservoir, as proposed by the old de Lesseps Company.

If this is at all feasible, and the cost not so great as to be prohibitive, under the present circumstances, then it would seem that this plan should stand first on the list for consideration. On the other hand, should the plan be found impractical, then, certainly, the plan for a tide-level canal, as outlined by Mr. Morison, deserves serious consideration by the Commission.

Mr. Harrison. C. L. HARRISON, M. Am. Soc. C. E.—The question whether the canal across the Isthmus of Panama should be a sea-level canal, with only tide locks, or a high-level canal, with a number of locks to reach the summit-level, has been a subject of discussion ever since the project was first proposed. The author has presented some of the difficulties involved in constructing a sea-level canal, but there are still others which can be inferred, but may be more specifically mentioned. If the Chagres River is taken into the canal at or near Obispo, then the canal from this point to Colon must be large enough to take the flood volume of the river at Obispo, and, in addition thereto, all the tributary streams between that point and Gatun.

Assuming that the depth is 35 ft., bottom width, 400 ft., with side slopes of 2 to 1, and that the discharge of the river is 100 000 cu. ft. per second; then, in the canal from Obispo to Colon there would be a surface slope of from 12 to 14 ft., and a mean velocity of more than 4 miles per hour, and perhaps a maximum velocity of 6 miles per hour, in parts of the canal. If this flood volume were to be of frequent occurrence or long duration, it might be advisable to make a larger channel and thus reduce the slope and the velocity of the water in the canal. But there is another phase of the subject which must be considered, *viz.*, sedimentation.

A channel of the foregoing dimensions would have, at low water, a cross-section of 17 450 sq. ft. If the discharge were 17 450 cu. ft. per second, then the mean velocity would be 1 ft. per second. At such a velocity the very fine particles of material suspended in the water would settle to the bottom of the canal, and sand would be deposited when the discharge was 50 000 cu. ft. per second. It is probable that a greater discharge than this would carry the suspended matter out into the bay at Colon, and, in addition, scour out some of the deposit which had been made at lower stages of the river. The net result of this would be that nearly all the sediment carried by the Chagres River would have to be dredged out of the canal between Obispo and Colon, or, out of the Bay of Limon at Colon, which would make the cost of maintenance very great.

The author estimates that "the time in which the discharge at **Mr. Harrison.** Gamboa would exceed 35 000 cu. ft. per second, or that at Bohio 50 000 cu. ft. per second, would probably not be more than ten days in twenty years." This would mean that there would be some sedimentation in the canal at practically all times; but there are no data to determine the quantity of suspended matter carried in the water or the quantity of sand and gravel moved along the bed of the river by the force of the current. At low and medium stages of the Chagres the water is not nearly as muddy as the Mississippi River above St. Louis, and carries less sediment than the Hudson River above Troy. The speaker has not observed the condition of the Chagres at flood times. Whatever this quantity may be, it is certain that a large part of it would have to be removed from the channel by dredging. This is by no means a difficult thing to do, but it is an item of cost for maintaining the channel.

In the sea-level canal it would also be necessary to provide some special method of taking into the canal all the streams from Gatun to Obispo. Much the largest of these is the Chagres at a point near Gamboa. The flood discharge at this point may vary for different years from 30 000 to 100 000 cu. ft. per second, and it must be conducted from the river, which is about 75 ft. higher than the bottom of the canal, into the canal in such a way as not to produce cross-currents which would impede navigation or erode the banks. This would require the construction of a dam across the river, together with an apron down to about the level of the bottom of the canal, and then the excavation of a new channel from this point to the river, on an alignment that would cause it to enter the canal in a direction nearly parallel to it. If this dam and the channel leading from it to the canal were not built, then the slope of the bed of the Chagres would be readjusted for miles up stream, and all material eroded in this readjustment would be deposited in the canal and would have to be removed by dredging.

These structures, for controlling a flood volume of 100 000 cu. ft. per second, would be very expensive. The cost would depend on the character of the foundations to be had and the kind of structure to be built, and also upon the distance the dam would be located up stream from the canal. The data are not at hand for designing these structures and estimating their cost, but it is certain to be a large item. Similar provision must be made for taking into the canal all the streams between Obispo and Gatun, but they are small compared with the Chagres. It may be that the author has included these two items in his estimated cost for a sea-level canal; but if he has not, then they may properly be added. Independent channels for the canal and the river would avoid these difficulties, but, unfortunately, no safe location for such a river channel has yet been found that could be constructed at a reasonable cost.

Mr. Harrison. From a personal study of the situation, the speaker believes that the summit-level, as proposed by the author and the Isthmian Canal Commission, with the long spillway at Gigante, is the best solution of the problem. It makes the control of the much-dreaded Chagres both easy and certain.

In the author's estimate of cost, 20% is added for engineering, policing, sanitation, and all other expenses not included in the unit prices for the various classes of work. This may seem excessive to those not familiar with the climatic conditions and the work to be done. The canal is located in a tropical country, which is hot for twelve months in the year and wet for from eight to nine months. Exposure to the night air or the midday sun is almost certain to produce sickness in the unacclimated peoples of the North, from which all the technical talent must be secured. In this climate, work and all other things must be done in moderation. It will require twice as large an engineering force as similar work would require in this country. The water supply and sanitation must be provided and maintained, which will be an item of considerable cost. The brush and timber must be cut and burned on the entire area of Lake Bohio, which is about 40 sq. miles. Should this not be done, the dead timber would float in the lake, impede navigation and interfere materially with the operation of the locks. The allowance of 20% seems to be too small, rather than too large.

In the first paragraph on page 43,* the author has outlined briefly a most important feature in the "conduct of the work," which, to neglect, is but to invite disaster, great increase in the cost of the whole work, and longer time for its execution.

There are but two seasons known on the Isthmus, the wet season, which is generally from May to January, and the dry season, which is generally from January to May, though in many years either of these seasons may begin earlier or later than the months above mentioned. The domestic water supply during the wet season is collected in tanks from the rain which falls on the roofs of the houses, and this, usually, is pure and always abundant, for it rains every day; but during the dry season the water is obtained from occasional rains and from water which was stored in the tanks during the wet season. The result is that the better class of people has a sufficient supply to last through the dry season, but the laboring class does not, and secures water from the most convenient streams or swamps. The dry season is usually considered much more healthful than the wet season. While on the Isthmus, as Chief Engineer for the Isthmian Canal Commission, the speaker collected health statistics which showed that the sickness and death rate were much greater during the dry season than during the wet season. An analysis of these statistics revealed the

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* *Proceedings*, Am. Soc. C. E., for January, 1908.

Mr. Harrison.

fact that in the dry season there was less sickness among the better classes of people and more among the poorer classes. This, no doubt, was caused largely by the different water used for domestic purposes during that season, and points to the great importance of having good water at all seasons for everyone. It is equally important to provide efficient sanitation at all times. If a good domestic water supply and proper sanitation are not provided, and an epidemic should break out during the first year of active operations on the Isthmus, it would not only result in great loss of life, but it would be exceedingly difficult and very expensive to secure an adequate force of workmen to complete the construction within the time contemplated.

The author, in the closing sentence of his paper, very forcibly states the sanitary conditions under which he expects the work to be done, and his estimates of cost are evidently based on such conditions.

The Isthmian Canal Commission, in making its estimate of cost, contemplated perfect sanitary and police control. From page 261 of its report, the following is quoted:

> "A considerable population has long existed on the Panama route, and it lies on a pathway of comparatively large trade, along which currents of moving people from infected places sometimes converge, thus creating conditions favorable to epidemics."

These conditions may be somewhat worse when a great many laborers are employed in building the canal. From page 262 of this report the following is quoted:

> "In order to exercise the rights necessary for the construction of the canal and for its management after completion, the United States should acquire control of a strip of territory from sea to sea sufficient in area for the convenient and efficient accomplishment of those purposes. Measures must also be taken to protect the line from unlawful acts of all kinds, to insure sanitary control, and to render police jurisdiction effective. The strip should be not less than 5 miles wide on each side of the center line of the Canal, or 10 miles in total width."

The treaty made recently between the United States and the Republic of Colombia for the construction of the Panama Canal, gives the United States sanitary and police control over a zone of territory about 3 miles wide on each side of the center line of the canal, or a total width of about 6 miles, which is a material reduction from the 10-mile zone recommended by the Commission. But this restriction is not as objectionable as placing the control of the towns of Colon and Panama, which are within the 6-mile zone, under the joint control of the native and United States authorities. It would be better if the control, during the time of construction were vested solely in the United States. Everyone coming to the Isthmus will pass through one or the other of these ports, and their inhabitants would be the first to be exposed to any contagious or infectious diseases brought to the Isthmus from other countries. It is important that the towns

Mr. Harrison. should be put in the very best possible sanitary condition and kept so during the whole time the work is being done. Enforcement of the regulation for this purpose would be easier under single than under dual control.

Mr. Bunau-Varilla. P. Bunau-Varilla, Esq.—In or about the year 1884 the speaker started the first dredge to cut the channel in the Bay of Panama, and at that time it was the opinion of nearly all the people on the Isthmus that every bucketful dredged from that channel would be washed back at once. For that reason Commander Lull, when projecting his line across the Isthmus, threw the entrance of the canal to the east side of the City of Panama in order to avoid the mouth of the Rio Grande, which is the point where the entrance is now located.

The work had been studied diligently by the speaker before he went to the Isthmus, and, on arriving there, he observed two facts which confirmed his opinion that the work would be successful and that the depth of such an entrance could be maintained. First, the entrance to the canal in Panama Bay is perfectly quiet, the little Bay of Panama being in a sheltered position within the larger bay, known as the Gulf of Panama, so that the heavy seas from the great storms from the Pacific do not enter it. The bay is remarkably still. Second, the sedimentation and consequent filling in of the bed of the channel in the bay would be caused by the simultaneous action of currents and waves; the waves put the sand and silt in suspension in the water and the currents transport it, and when an excavation is reached the suspended matter settles. Such a current exists; it flows continuously toward the west, but, owing to the complete and regular flow of water, there is practically no material in suspension.

Six months after the channel had been dredged it was examined by the speaker, who found that the depth in the center had been fully maintained. Although the side slopes were modified, the depth on the axis was fully maintained. This is proof that the work in the bay will be absolutely successful. The channel is already dug for a part of the distance, and ships enter and follow it. This question is not open; it is closed. It is not a question of the future; it is settled.

In relation to the question as to the lock canal and the sea-level canal, the speaker has no more fear of sediment in the latter than he has of sediment in the channel in Panama Bay.

The water of the Chagres does not flow through volcanic ground. The word "volcanic" must not be used. "Volcanic" ground means a ground filled with active volcanoes and which produce rock which is very soft and liable to decay very easily under the influence of the atmosphere. It is true that in a country where there are active volcanoes, the waters of the rivers carry an enormous quantity of sediment. The Isthmus of Panama was formed in remote times, before the human race appeared upon the earth, about the end of the tertiary

Mr. Bunau-Varilla.

or at the beginning of the quaternary period, and at the time these volcanoes were active, they did not eject lava, but that stronger material called basalt.

The rocks and clays of Panama are extremely stable, and, as a rule, the waters of the Chagres are pure and clean. Of course, during great floods there is a certain amount of erosion, but, at such times, if the water is received into the canal, there will be, also, an increased current, which will take up the silt washed in and carry it through the canal and out to sea. The speaker has no fear upon that point. Of course, there will be the work of maintenance, but, for a canal of that importance, what is it to take out 500 000 or 1 000 000 cu. m. every year? It is absolutely nothing. In the Suez Canal more than that quantity is taken out, and the Suez Canal has not been a failure, up to this time.

There is another very important point: The idea of M. de Lesseps, that a sea-level canal, which has been so successful at Suez, is the final solution for Panama. A sea-level canal must be made and will be made at Panama. There will be a time when the importance of traffic will justify a passage of the highest class, that is, a sea-level canal. But is it justifiable to wait ten years longer in order to give the world the benefits of that great work? Is it not proper to take the intermediate solution, the lock canal? The lock canal should be constructed now, for that assures an earlier completion of the long expected work. It will give a very satisfactory canal for a number of years. But the time will come when the character of the traffic will be so transformed that it will demand the transformation of the lock canal into a sea-level canal. This can be accomplished without stoppage of navigation, although it will cost much more to finish the canal while it is in operation than to make it prior to such operation.

From all standpoints, the speaker would justify the lock canal now; it will answer admirably the needs of navigation for a limited number of years—perhaps twenty or thirty—but thirty years will not pass before the absolute necessity of a sea-level canal will be seen, and plans for its transformation will be begun. Ten years' earlier opening justifies the less satisfactory form, to be in time transformed into its final shape, the American Bosphorus.

Mr. Morison.

GEORGE S. MORISON, Past-President, Am. Soc. C. E. (by letter).— Replying to Mr. Meigs' first question, the Chagres is not unlike many rivers in the eastern and southern parts of the United States. It has about the same range between maximum and minimum discharges, and is subject to the same hydraulic laws. There is only one respect in which it differs from them essentially. The rainfall in the Chagres basin is double what it is on our rivers; the result is that the same maximum flood is obtained, from an area of less than 900 sq. miles of drainage basin, which would come from four times this area in the

Mr. Morison. United States. Twice as much rain must be disposed of; this means either a larger flood or a smaller basin; in the smaller basin the flood has less distance to travel. With one-quarter the area of drainage basin, we have one-half the aggregate rainfall with one-half the distance to run off, which means the same maximum discharge but a flood lasting but half as long.

The Chagres, under ordinary conditions, is a clear stream with a fall of from 2 to 4 ft. to the mile. In the upper river there are no signs of silt or other alluvial deposit, but between Alhajuela and Gamboa there is some small amount of bottom land and silt deposit. The erosion of this bottom land in times of flood is apparently the chief source of sediment in the lower river. With the high-level canal plan this silt region will be drowned and this erosion stopped. The amount of sediment which will be brought into Lake Bohio is less than must be expected in any of our Atlantic harbors. With the tide-level canal the danger will continue, but the amount of such erosion can hardly be considered excessive.

With reference to the difference between the elevation of the Chagres in flood times at Gamboa and the bottom of the proposed tide-level canal, anything approaching a vertical drop, if it were possible, would be destructive. Such a drop, however, is impossible. The bed of the Chagres is earth, not rock. If it were rock, this would be the place to build the upper dam. If ever a tide-level canal is built, the broad channel which will carry off the drainage of the Chagres must be extended at least a mile up the valley beyond the canal, and such barriers must be constructed as will retard the flood in the river and thereby reduce its destructive force. No plan has ever been worked up in detail to meet this provision, the tide-level canal being removed from present consideration for the reasons given in the paper.

The estimates made in the paper are adapted from the estimates prepared by the Isthmian Canal Commission and used in reaching its conclusions. The principal savings are in the Bohio Dam, in the reduced amount of excavation in the Culebra Cut and the shallower portions of Lake Bohio, in the reduced excavation on the Pacific level, and dispensing with the diversion channels on the Chagres above Gatun, the Gatun Channel being retained. The cost of the canal itself from Colon to Lake Bohio is slightly increased, the Commission's estimate of the two being as follows:

	Commission's Plan.	Tiger Hill Line.
Atlantic Maritime Level...........	$19 006 199	$12 184 981
Tiger Hill Level..................	......	5 638 874
" " Lock and Spillway......	......	5 024 056
Bohio Locks.......................	11 567 345	9 014 632
	$30 573 544	$31 862 543

Mr. Morison.

The increase of $1 290 000 is more than balanced by a saving of $2 700 000 in the cost of the diversion channels. By removing the canal to the more direct line, the present canal, which is now actually the bed of the Chagres, is left available as a diversion channel, a use to which it is admirably adapted.

There are four questions which the writer would like to have discussed at this time:

The first of these is the relative merit, under the circumstances, of the tide-level and the high-level canal, the difference of cost and time being as now estimated. The great difference is the time required for construction, which would be fully ten years longer for the tide-level than for the high-level canal. The tide-level canal could not be without locks. A 20-ft. tide on the Pacific side makes a tide lock necessary. The gates of this tide lock could stand open at certain stages of the tide, so that it would not absolutely limit the length of ships passing through, but with a tide-level canal, the same limiting sizes would exist for the greater part of each day as with a high-level canal. The tide-level canal would be a canal for the whole width of the Isthmus, although a portion of it would be pretty wide. The advantages of the inland lake would be lost. The inland lake makes two short canals with good anchorages and good repairing ground between —this is no small advantage.

The next question is whether it is important to try to reduce the size of the locks below the great lift proposed in the plans of the Commission for the locks at Bohio. By using the third lock at Tiger Hill, as described in the paper, the normal lift of the locks is reduced from 42 to 28 ft. There is not the slightest doubt that a lock with a 42-ft. lift can be made and used, but an injury to such a lock in case of accident would be much more serious than to a smaller lock of less lift. Whether there is any more danger of injury occurring is a point which may be considered. Even with three locks, the time of passing through the eastern canal will be a little less than the time of passing through the western canal. Which is to be preferred, the two locks of 42-ft. lift or the three of 28-ft. lift?

The third question is the water supply for the summit level of the canal. The Chagres River supply is adequate for all but three months of the year. This deficiency can be obtained by drawing water from the lake. It can be obtained by another reservoir above Alhajuela. In the writer's judgment, it is best to postpone the final decision; to build the canal with no provision for this additional water, but, for the first few years it is operated, to allow the depth of water in the canal during the extreme dry season to be reduced, perhaps from 35 to 33 ft., and, ultimately, to provide a reservoir above Alhajuela to make good this deficiency. This would save something in the first cost of construction, and would ultimately give an indefinite supply. Is it right or wrong?

Mr. Morison. The fourth question is whether it is expedient, in a harbor like Panama Bay, with an extreme tide of 20 ft., to construct a channel giving a maximum depth at all stages of tide, at an additional cost of about $5 000 000. The reduction of this channel is one of the items which has reduced this estimate below the Commission's estimate. With a channel 35 ft. below mean tide, a ship requiring 25 ft. could always come in. A ship requiring 35 ft. could come in 18 hours out of the 24. How much is it worth while to pay for this additional 6 hours a day for ships of extreme draft? At high tide, with the channel as described in the paper, the depth would be 45 ft. With a channel 35 ft. deep below low water, it would be 55 ft. There are few harbors with large tides where anything like this has been done.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

THE PRESERVATION OF MATERIALS OF CONSTRUCTION.

An Informal Discussion.*

By Messrs. William Barclay Parsons, Rudolph P. Miller, George Hill, Oscar Lowinson, Henry B. Seaman, George A. Just, A. Gideon, Franklin Riffle and Edward P. North.

Presented at the Meeting of February 4th, 1903.

William Barclay Parsons, M. Am. Soc. C. E.—Engineers are accustomed to put into structures materials which are expected to remain unimpaired for a great many years, but are obliged to take a great deal on faith; therefore it is especially interesting to examine any material whose age can be thoroughly authenticated, and whose state of soundness or decay can be ascertained accurately. Mr. Parsons.

Last autumn, while inspecting the subway construction of the Metropolitan Railway in Paris, the speaker was shown some timbers which had formed part of the foundations of an old building erected in the fourteenth century; and the chief engineer, Mr. M. F. Bienvenue, has very kindly sent some pieces of the piles and the timber grillage, which now, on his behalf, and in his name, the speaker takes great pleasure in presenting to the Society.

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* The discussion of this subject, for which no formal paper was presented, is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion. (See Rules for Publication, *Proceedings*, Vol. XXV, p. 71). Communications on this subject received prior to April 24th, 1903, will be published subsequently.

Mr. Parsons. The following is a translation of the letter accompanying these specimens:

On October 5th, 1902, while excavating the trenches under the Place de la République, for that part of the Chemin de Fer Metropolitain between Courcelles and Menilmontant, there was discovered a great quantity of oak piling supporting an oak platform.

The piles were from 1.50 to 2.00 m. in length, and from 20 to 25 cm. in diameter. The lower part of each was sharpened to a square point, but bore no traces of iron banding or of crushing. The width of the platform timbers varied from 50 to 70 cm., and their thickness from 10 to 15 cm.

This wood, which was a true pile foundation, has been identified as composing part of the foundations of the old "Porte du Temple," having formed part of the wall of Paris during the reign of Charles V (1364–1380). The preservation of the wood is perfect, notwithstanding the fact that it has been in place since the fourteenth century.

The lower part of the piles was embedded in a green argillaceous sand, while the upper part was in a blackish, marshy soil, filled with sulphurous and ammoniacal gases.

The lower part of the platform was about at elevation 29.00 at the point where it was uncovered, the elevation of the surface of the ground at the Place de la République being about 37.00.*

On top of the specimen of the pile may be seen fragments of the cement or lime probably used to level out under the grillage. When the wood was received, a few weeks ago, it was intact, but, by lying in the speaker's office, the heat has produced certain checks and cracks. The pile is in a perfect state of preservation, the wood is soft—not hardened at all—and resembles a piece of wood which has been in the ground but a short time.

The two specimens of the grillage on top of the piles are also checked, owing to the office heat, but, on both pieces—the larger piece especially—remnants of the bark may be seen, showing that even the bark is still intact.

It is interesting to recall that these pieces of wood were put in the ground at a period before the discovery of America equal in length to that period which has elapsed since the Declaration of Independence.

As indicative of the fact, however, that French soil is not the only kind which will preserve wood, sections of the first water pipes laid in the City of New York, by Aaron Burr's Company, about the year 1800, have been found recently in Centre Street and the adjoining streets, by the contractors for the Rapid Transit Commissioners. These are not as old as the French wood, but, nevertheless, they are sufficiently venerable, as they have now passed into their second century. Some of the pipes are quite decayed where they have been buried in dry sand, but where there has been moisture in the sand, the wood is still sound.

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* The original letter of Mr. Bienvenue, together with the samples of wood, and a plan of the exact location of the old foundation, are on file in the Library.

Rudolph P. Miller, Assoc. M. Am. Soc. C. E.—Considerable interest has been aroused by the demolition of a modern steel-skeleton building in New York City. Many varying expressions as to what would be revealed when the steelwork should be exposed, especially as to its state of preservation, led the Superintendent of Buildings for the Borough of Manhattan to have the building examined carefully during its demolition. Photographs and notes have been taken since the work of demolition started about six weeks ago. The building has not yet been taken down completely, and a full report on the matter is not yet prepared. The photographs, unfortunately, do not show the condition of the material, it being difficult and practically impossible to distinguish on the pictures between rust and discolorations due to the adhesion of particles of the fire-proof coverings, yet they can serve conveniently the purpose of illustrating some of the facts to be noted. **Mr. Miller.**

The building was situated on the north side of Forty-second Street, running from Broadway to Seventh Avenue, and was known, variously, as the Thorley Building and the Pabst Building.

It was erected about four years ago, having been started in October, 1898, and completed about a year later.

The steelwork was put in during the months of December, January, February and March. The structure was about 25 ft. deep, of an average length of about 54 ft., and was nine stories high, or about 108 ft. The foundations were on rock.

The construction consisted of a frame of Z-bar columns, with beams and girders carrying the floors and walls at each story. The walls were of brick, except those of the second story, which were of limestone, the first story having an iron front.

The steelwork when delivered at the site had received one coat of carbon paint. It was put up as fast as delivered, and was followed very quickly by the masonry. In some portions of the work the masons were so close behind the erectors that part of the framework probably never received a second coat of paint.

It is interesting to note that the steelwork in the fourth, fifth and sixth stories showed more rust than that in the stories either above or below them.

The interior columns, for the most part, were enclosed in hollow terra cotta blocks, but by no means always solidly. Along the webs of the Z-bars, at right angles to the web of the columns, the contact between the steel and the fire-proof covering was generally complete. On the other sides of the columns, however, the terra cotta blocks were often placed spanning the space between the Z-bars, leaving a void between the fire-proofing and the main web of the column. The steelwork was in equally good condition on all sides of the columns. These columns showed little patches of rust here and

Mr. Miller. there, but none that could not be explained by some cause at work before the steel was put in place. For instance, the rust may have set in under the mill scale before the columns were painted or set, not being visible from the outside, as the mill scale is a non-corrosive oxide of iron. There was in no case a general or extended rusting of any steel member. The points where rust showed in the columns most generally were the rivet heads and the connections.

The connections were the parts most affected by rust. The worst example of corrosion in the building, thus far, is illustrated in Fig 1, Plate XXX. In this case, practically the entire inside of the splice plates, where they show black on the photograph, was rusted, and the faces of the connections that were in contact were rusted. The speaker has no doubt that, in setting one column above another, considerable force was used, and the friction between the parts was sufficient to rub off the shop coat of paint. The heads of the field rivets were the places where rust was oftenest found, yet in no case, except in that illustrated, was the rust of a thickness that could be measured by ordinary means. In this case the thickness was from 0.02 to 0.025 in.

The wall columns were encased in brickwork, 8 ins. thick on the outside and 4 ins. thick on the inside, the inside 4 ins. being what is known as furring bricks. In some of these columns there were indications of rust in layers, as shown in Fig. 2, Plate XXX. The steel was free from rust where the cement mortar came in contact with it, but between such points it appears as though the porous brick permitted the entrance of sufficient moisture to start rust; but, again, in no measurable quantity. This is in accord with observations made in a number of other instances where alterations in a building have exposed steel columns.

The floor beams and girders throughout the interior of the building, except the top flanges, were encased in the cinder concrete forming the floor arches of the building. The concrete was made up in the ordinary proportions for that form of construction (that is, 1 part cement, 2 parts sand and 5 parts cinders), and was a fair sample of cinder concrete as generally used in building construction in New York City. Yet the steelwork thus protected was remarkably free from rust. Where there was any, it was in very small patches, more generally on the rivet heads, and it was probably there before the floor arches were placed.

Practically the only place where any rust was shown was on the webs of the channels forming the frame for the stair-well and elevator shaft, and then it was on the shaft side, where it was not covered with some protective material other than paint.

The wall girders, encased in brickwork on the outside, showed signs of rust along the edges of the flanges toward the outside of the building. This was more especially true of those in the northerly

PLATE XXX.
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MATERIALS OF CONSTRUCTION.

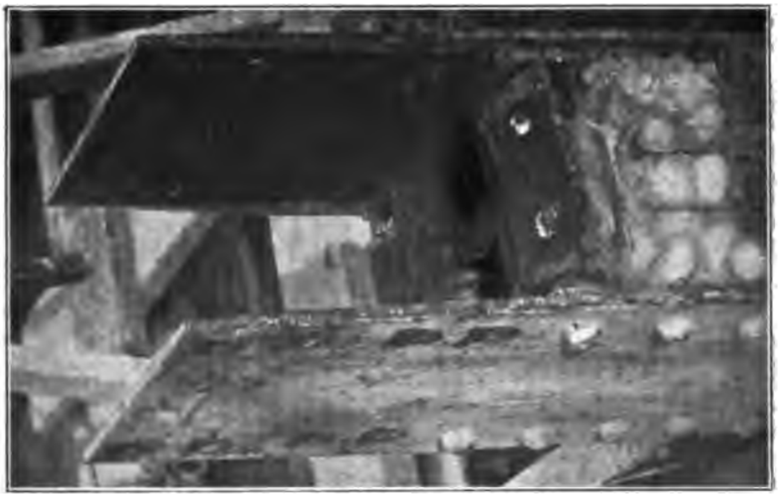

FIG. 1.—CORRODED SPLICE PLATES.

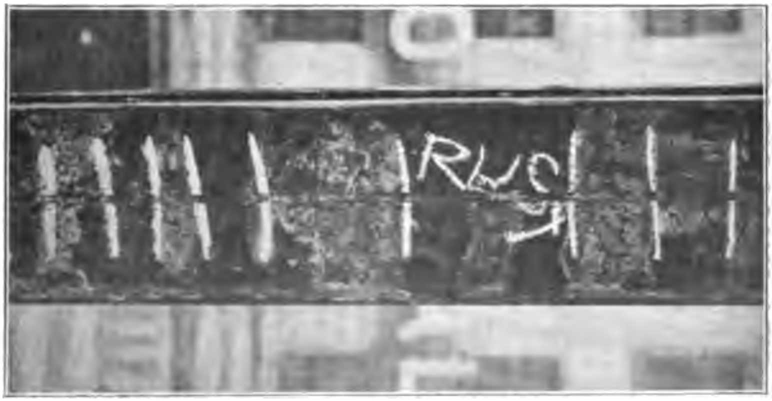

FIG. 2.—RUST SHOWING ON STEELWORK WHERE CEMENT WAS NOT IN CONTACT WITH STEEL.

wall, which, for most of its height, was exposed to the weather. Mr. Miller. The adjoining building to the north was of four stories. The flanges of these wall girders came within about 2 or 3 ins. of the outside of the wall of the building.

A built-up girder, in the westerly wall, at the second-story floor level, shows two patches of rust on the web of the girder. No explanation has been found for these patches of rust, which are exceptional. The sides of the girders were thoroughly encased. It may be remarked that the present indications are that the steelwork yet to be removed from this building, in the basement and cellar stories, will show considerably more rust than any taken out of the upper part of the building. It should be noted that the steelwork was erected during very bad weather, and the location was a particularly damp one. On one or two occasions the work had to be stopped on account of snow storms or rain.

The concrete of the floor filling was segmental in form, and was supported by temporary centering, consisting of $\frac{1}{2}$-in. round bars spaced about 9 ins. apart, which stiffened the wire netting. This centering was rusted throughout the building—generally, however, only on the side exposed—and the rust is not more than would develop during the drying out of such a floor construction. This floor was hidden and covered over by a flat ceiling, secured to the lower flanges of the beams. The rusting evidently did not continue after the floors had dried out and the ceiling had been put in place.

The boiler stack of the building was of $\frac{5}{16}$ and $\frac{1}{4}$-in. sheet-steel, and was covered with asbestos.

The stack was completely covered with rust, the asbestos covering evidently offering no protection, although the galvanized wire woven into the asbestos covering was as bright as the day it was put in.

The expanded metal used in the partitions was very badly rusted throughout the building. This may have been rusted when put in, for such material is generally sent to a job in bundles, and lies about, exposed to the weather, for some time before being put in place; but the material of the partitions, which was a patent plaster, evidently did not arrest the corrosion, but probably increased it.

One 6-in. floor beam, shown in Fig. 1, Plate XXXI, was rusted badly for an area of, perhaps, 1 sq. ft.; but all the indications are that this beam, over this particular spot, was never painted. Evidently, the beam was marked at this place at the mills before being painted, and, when painted, this spot was not touched, in order not to obliterate the marks.

All steelwork erected in New York City is supposed to receive a coat of paint after being set, but this is not always done, for several reasons—sometimes to save the expense, which the speaker is sure was not the case in this instance; often because of the untrustworthiness of

Mr. Miller. the workmen, who shirk those parts which are difficult of access; again, when the masons are following close behind the steel erectors, they will not wait for the painting. The tops of beams and girders do not often get the second coat of paint because the erectors in climbing over the steelwork are more likely to slip on the freshly painted surfaces. Fresh paint in the connections is likely to spurt out during riveting, and therefore connections are often neglected.

To show how the beams come to the site unpainted sometimes, a photograph of some steelwork delivered for a new building in New York City is shown in Fig. 2, Plate XXXI.

Where the shop marks are placed on the beams, they have not been painted over at all, and, in this instance, the beams have already rusted at such places. The same beams also show indications of rust along the connections, as indicated by the chalk marks—not much, to be sure—but whether or not this incipient corrosion will continue is an open question. It is very doubtful that the rust will be scraped off before the next coat of paint is put on, and if not, it is doubtful whether the paint will be of much use. It is difficult, too, to follow the painting during erection. To meet this difficulty, some architects specify that the steel shall be painted with red lead before delivery, and with carbon paint during construction. They can then tell by the color whether or not the second coat is complete. All unpainted steel that came out of this building, whether enclosed or not, was rusted.

The speaker has been describing the places where rust was found, but it should be stated that the quantity of rust in this building was small. Most of the cases were found in the fourth and fifth stories, where the rust spots were most frequent. The steel frame, generally, was remarkably clean and free from rust. The conclusions to which these studies lead simply corroborate those of which engineers have already felt fully convinced—that paint, applied properly, is a protection to steel, at least for a certain time; that cement mortar is a very efficient protection for steel, and that ordinary cinder concrete also serves this purpose quite satisfactorily.

Mr. Hill. George Hill, M. Am. Soc. C. E.—The speaker has thought of this subject under certain headings:

First.—The preservation of materials of construction against atmospheric deterioration, a branch which can be dismissed, because, in general, the use of such materials as will be safe against the action of frost or the elements is always attempted.

Second.—The preservation from injury due to soot or dirt from the atmosphere, a branch of the subject with which the speaker has had very little experience. Many handsome buildings are spoiled by reason of the soot, and attempts have been made, by the use of glaze on terra cotta, and by various forms of materials supposed to be impervious, or by paraffine compounds applied to the exposed surfaces, to prevent this, and it is claimed that this has been done successfully.

PLATE XXXI.
PAPERS, AM. SOC. C. E.
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MILLER ON PRESERVATION OF
MATERIALS OF CONSTRUCTION.

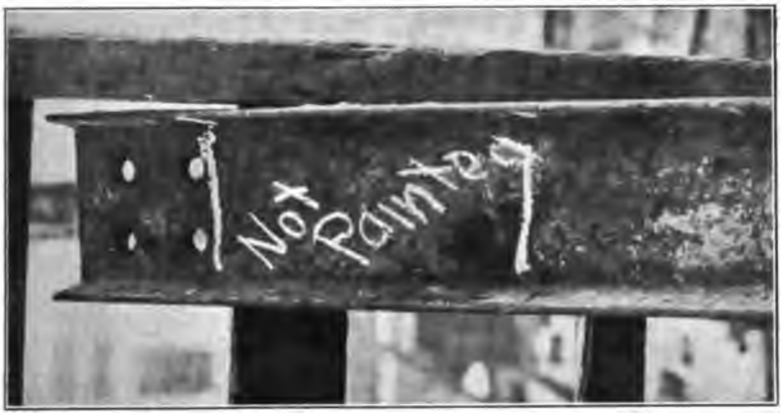

FIG. 1.—SIX-INCH FLOOR BEAM.

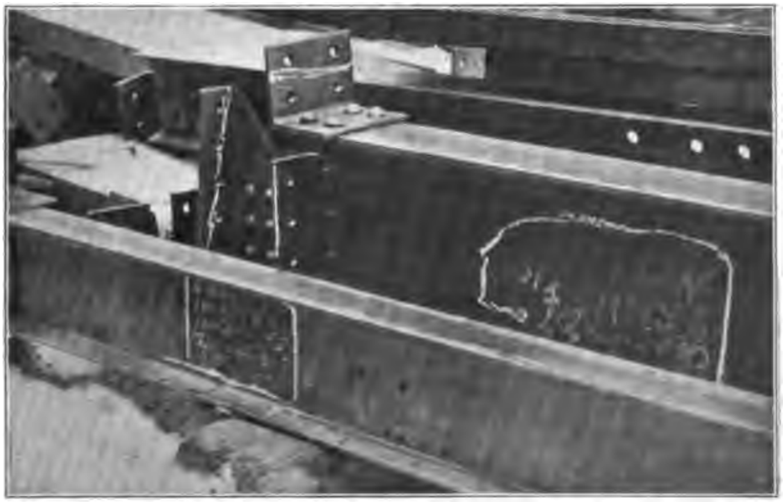

FIG. 2.—STEELWORK; PAINTED, EXCEPT WHERE SHOP MARKS ARE SHOWN.

Mr. Hill.

Third.—Protection from dampness striking through. In that particular line, the speaker has had some experience with certain walls made of patent plaster, Portland cement and sand, 2 ins. in thickness, and used as external walls of manufacturing buildings, coated with some of the compounds which are on the market, and has found that they were efficient. He has also had experience with brick walls, coated on the inside with similar compounds, and has found that the dampness was excluded. In general, it may be said that there are certainly half a dozen different compounds, which can be obtained at a reasonable cost, which will protect buildings from deterioration through the striking in or the transmission of dampness.

Fourth.—When it comes to the preservation of metallic structures, the speaker thinks that this discussion should be in the nature of an experience meeting, and, in general, the failures rather than the successes should be described. For instance, during the last five years the speaker has erected quite a number of buildings with external curtain walls, composed of hard plaster, Portland cement and sand in equal parts, the scratch coat being applied to uncoated metallic lath, making the thickness of the scratch coat about 1 in., then a surfacing coat of Portland cement, ½ in. thick, was applied on each side, making the curtain walls a total thickness of about 2 ins. These buildings have been put up at various times, the latest one being about four years old. All are in first-class condition at present, with the exception of one.

This building is one of four, and was erected in the winter. The scratch coat was alternately frozen and thawed several times. Two years after the building was finished it was found that the outer surfacing of cement was cracking and falling off. Sheets having an area of 8 or 10 sq. ft. came off, leaving the scratch coat bare. This was left alone, and the deterioration or destruction of this wall has been going on for about two years. The entire wall now is in rather bad shape, and it is proposed to put it in good order. In every case there was a separation between the finishing coat and the scratch coat, and, in general, the wire lath, where it was on the surface of the scratch coat, or where the scratch coat came very close to the surface of the lath, was very badly rusted; but, in places, this was little more than a discoloration. In other places, the wire lath, while rusted, was probably in exactly the same condition as when the plaster was first applied to it; because sometimes several days elapsed after the bare lath was erected before it could be covered, and there is no doubt that during that time it rusted.

The adjoining building, erected in the following spring, is in absolutely perfect order to-day, and all the other buildings are in equally good condition, so that this failure was due to the alternate thawing and freezing of the scratch coat, which prevented the forma-

Mr. Hill. tion of a proper bond between it and the surfacing coat. It may be that the surfacing coat, which was of undue thickness, reaching in places as much as 1 in., was too thick, and that that was responsible for a small part of the trouble.

Fifth.—In the protection from oxidation of such a metallic structure as Mr. Miller has described, the speaker has observed a few cases where the paint on the steel has been protected with metal lath and Portland cement, and in every case has found that it afforded a sufficient protection.

In the matter of painting, although personally interested in one paint concern and very well satisfied as an individual with its product for forming a preservative coating, it is the speaker's belief that there are several paints or preservative coatings for metallic structures, to be had at the present time, which will give satisfactory surfaces when applied properly; in fact, the intelligent application of the covering, in accordance with the manufacturer's directions, has almost as much to do with a satisfactory service as the composition of the paint.

Sixth.—In protection against fire the speaker had one experience which is instructive. The building was of the ordinary steel-skeleton type, and a fire occurred on the fifth floor, the heat being sufficiently intense to soften the steel steam-pipe risers, so that the deflection in some cases was as much as 6 ins. It also melted the brass air-valves on the radiators. The flames passing out of the windows melted the solder in the copper cornice, five stories above. The Fire Department was able to erect a water-tower and direct the stream from it horizontally into the building, and the fire was put out by drowning; that is, the entire floor was filled until the water flowed out over the window sills. This stream struck several of the columns, all of which were wrapped with wire lath and plastered with Portland cement and sand, with a thickness of about ¾ in., on which the white coating was applied. This covering resisted the effects of the heat and the hose stream in every case except one, where a portion of the covering, about 18 ins. long and 12 ins. wide, was torn off; but, evidently, that did not occur until the fire was practically out, because the paint on the column—the building had been erected about a year and a half—was intact and not blistered by the heat.

Some years ago the speaker made a series of experiments for the representatives of the System Mélan, using stone concrete with Portland cement surrounding T-bars of steel bent into the segment of an arch. He found that in every case, although the steel sections had been exposed to the weather for from 60 to 90 days unprotected, wherever the concrete had been in contact with the steel, no rust showed at all. The steel was not painted, and showed bright; but wherever there were voids in the concrete, due to the use of rather dry concrete with a stone aggregate, rust had set in.

In the tests made, for the expanded metal companies, in Long Island City, the slabs were generally made of very wet cinder concrete, and, during December and January, for from 30 to 45 days, were exposed to atmospheric conditions. The steel which was embedded in the cinder concrete, or in the gravel concrete, as the case might be, was absolutely unchanged after the destruction of the slabs. A chunk of cinder concrete, in which expanded metal was embedded, and which, when it came to the speaker, was reputed to have been exposed to atmospheric conditions for five years, was kept for about a year on his window sill, where it was exposed to atmospheric conditions until the expanded metal which projected was rusted about half off. It was then split, and it was found that the expanded metal embedded in the concrete was clean and bright. **Mr. Hill.**

Nearly two years ago the speaker lined a very bad shaft, for the Lackawanna Railroad Company, at Scranton, Pa., with cinder concrete and expanded metal. The shaft was through quicksand, about 60 ft. to rock, and was notorious for its bad character. The wood lining put in previously had been in place about six years, and was generally rotted through. It was necessary to replace it either with wood or masonry. Expanded metal was used, with Atlas Portland cement and furnace cinders taken from the ash pile at the power-house operating the breaker in connection with the mine. The cinders were taken from this pile without any selection, and without screening. A few days ago an examination of the lining was made, and it was found to be in as good condition as when put in. The condition of the expanded metal could not be ascertained very well, but if there had been any deterioration, if the Portland cement and the cinder concrete had not been an absolute protection to the iron, the character of the water surrounding that shaft and constantly flowing through it was such that it would have eaten up every portion of the iron within a year. It is believed that under such conditions the cinder concrete acts as an absolute protection to the steel.

It seems to the speaker that it would be of great interest, and a great benefit to the Society, if the Special Committee on Uniform Tests of Cement should have its scope extended, so that an investigation could be made of the effect of neat Portland cement, Portland cement used with various aggregates and Portland cement adulterated with various lime or patent materials, in respect to the preservation of steel. The Society can certainly do very useful work along this line, and if such tests were extended to cover the use of cement in the way in which it is actually used, so that some analogy could be drawn between the test as made and the use to which the cement is put, its utility would be increased still further.

Among the practical builders in New York City, there are a good many curious notions. Some of them have told the speaker, with great

Mr. Hill. seriousness, that it was very dangerous to embed a steel grillage in neat Portland cement; that the cement burned the steel, and that this effect was entirely overcome if a little lime were added. Others have said that it was not possible to grout a cast-iron base with pure Portland cement, because it invariably swelled, and so on, through the whole list. Everyone who has done any work has undoubtedly heard the various peculiar notions of the "practical" men, those who have a certain amount of hand knowledge, and who do not use their heads in connection with it.

As far as the speaker's observation goes, steel which has been properly embedded in concrete remains absolutely unimpaired and perfect in its condition. The effect of painting or oiling the steel before the application of concrete does not seem to be injurious, in view of the fact that the steel cannot always be covered immediately. In the protection of relatively large sections—with the exception, perhaps, of the steel which goes into the grillages, where a most perfect covering is desirable—it would be well to give the steel one or two coats of paint; but, for the grillages, especial care should be taken to cover them thoroughly, and, in such cases, as intimate a contact as possible should be secured between the concrete and steel.

In the application of steel for the re-enforcement of concrete, the fundamental principles are that the steel should be used in small sections and of such form that it will retain its position in the mass of concrete by reason of the form rather than by reason of the adhesion between the concrete and the steel; so that a preservative coating would have only a small influence on the strength of the combination; but, as the preservative coating is expensive, and makes the steel unpleasant to handle, and as the steel can always be embedded in the concrete promptly and thus preserved from initial rusting, the speaker thinks it well that the smaller sections should not be coated.

In the mixing of concrete, the usual practice, or, at least, the practice that the speaker was taught, is wrong. It is very much easier to make concrete too dry than too wet. The concrete in the Pabst Building, described by Mr. Miller, was mixed so wet as to be really muck, and was deposited practically without tamping.

In the last few years the speaker has used a great many thousands of barrels of Portland cement in concrete, almost all of which has been deposited without tamping, and all of it so wet that the natural slope was about 30° from the horizontal. His theory of the matter is that the very fine portions of the cement are washed down in that way, and coat the steel perfectly and fully, and that the excess of water renders any extensive tamping unnecessary and thereby effects a material economy in the cost of making and depositing the concrete. The speaker's observation of a great deal of concrete deposited, usually in thin sections—sections of from 4 to 8 ins. in thickness—is that this excess of moisture does not result in a porous concrete, nor does any noticeable shrinkage result; but that, on the contrary, it saves time. Mr. Hill.

One serious danger in concrete deposited during warm weather is that of an insufficient quantity of water, and a consequent drying of the concrete. The following experience is an illustration of this danger. Some twelve years ago, when the speaker was designing engineer for a firm of architects, it was decided that a certain windmill tower, with a heavy stone base, should contain a steel tank 50 ft. high and 14 ft. in diameter, the stone base being about 25 ft. in diameter. This stone base was to enclose a small engine-room, so that the tower had to be supported directly over the engine-room. A steel angle-iron skewback was put in and a Guastavino arch formed. Then, to make a leveling for the tower, a contract was made with a certain party to fill the haunches, to a minimum thickness of 1 ft. over the crown, with Portland cement and broken-stone concrete. The men were careful to do what they called a good job. The concrete was mixed very dry—not quite as moist as brown sugar. It was thoroughly well tamped, and then exposed to the sun and wind, and dried out very quickly. The tower was put on before the speaker had an opportunity to inspect it. That concrete was just about as good as so much dried mud, and all of it had to be scraped out with shovels, with the occasional assistance of a pick and crowbar.

Mr. Parsons. William Barclay Parsons, M. Am. Soc. C. E.—The preservative effect of cement mortar on steel has been noticed by the speaker in the case of some steel beams taken out of the sidewalk vault of a building on Fourth Avenue, in New York City. These beams were put in place in 1880 or 1881, so that they are now about twenty-two years old. They carried brick arches for most of their length, but the outer or curb ends were embedded in rubble masonry.

Above the jack arches a space of 2 or 3 ins. was filled with ashes, on top of which the sidewalk was laid.

The beams are in very good condition, except at the ends near the curb, and where the rubble masonry had been cracked by the impact of wheels against the curb, thus permitting water to percolate and attack the steel.

On comparing the part which had been embedded in the masonry with that part which had carried the arches, it was noted that the latter, although it had never been painted, was practically free from rust.

The speaker would like to ask the members to give their opinions as to whether steel should be painted before being embedded in masonry, or whether it is better to let the cement come into direct contact with the fresh metal. This is an important question, because a great deal of steel is now being embedded in concrete.

Mr. Lowinson.

OSCAR LOWINSON, Assoc. M. Am. Soc. C. E.—In reference to the protection of metallic surfaces, especially those exposed to moisture, the subject that has troubled most engineers has been the question of what is known as the progressive oxidation of those surfaces; for the life of a structure is really dependent upon whether oxidation which started at any period in the life of that metal will continue.

Now, in connection with structural steel, it has been the speaker's custom to try to get all the rust off the metal before painting it. He has made examinations of metal painted with various kinds of paints, and found that oxidation frequently continued and caused increase in rust, very slightly perceptible for a while, but after several years becoming scaly and throwing off the paint. The proper protection of that metal by paint, he thinks, is necessary, especially when it is to be embedded in masonry, or in any case where that metal will be exposed to moisture, because iron or steel will only rust when oxygen, together with moisture and carbonic acid, is present.

It would be advisable at all times to make sure to have a protective coating of paint of some kind in addition to the pure cement. It is undoubtedly true that Portland cement is a good protective coating for steel, but it is also true that it is impossible to protect steel with a wash of Portland cement, for the reason that it will not adhere to the steel.

One question that has been touched slightly by Mr. Hill is occupying the attention of many architects at present, and, that is the protection of walls in order to prevent the attacks of the elements, principally the penetration of moisture. In fire-proof buildings, an effort is made to do away with furring, because it is found that in most cases a furring course is not sufficient to prevent moisture from coming through the wall and destroying the plaster.

There are on the market at the present time a score of what are known as damp-resisting compounds, and which are supposed to serve as moisture repellants. Most of these are of no value whatever for this purpose.

These damp-resisting compounds may be divided into two classes: Those which are put on the inner surface of an exposed wall, the plaster being applied directly on the paint; and those which are applied on the exterior surface of a wall, over which is put a coat of good paint, for a finishing surface. Of the first variety, the only correct kind is a hydrocarbon compound, which should be free from tar, pitch and oil, and should also be proof against alkali. It should be a sticky or non-drying compound, to which cement mortar or plaster will adhere permanently, and which water or moisture cannot penetrate.

The second variety, for exterior use, is a chemical compound, of the nature of a quick-setting, very finely divided, hydraulic cement, applied as a paint, which, when partially set, cannot wash off in a rain storm, and which will take linseed-oil paint without peeling. An ordinary cement wash will absorb moisture, and disintegrate; not only this, but it is also common experience that linseed-oil paint will not adhere to a cement surface. The reason is that, in the hydration of cement, Ca_2O is set free, and, with linseed oil, forms a lime soap, which will wash off. Mr. Lowinson.

The theory of the setting of cement, largely accepted, is that an excess of moisture does not ordinarily injure it, but the cement in its setting has the inherent ability of rejecting all the unnecessary water in order to permit it to set properly and attain its hardness.

A sufficiently thick layer of cement mortar on the outside of a brick wall forms an excellent water resistant if it has time to set before moisture or frost attack it. There are two or three materials on the market at present, which the speaker believes are made of Portland cement, with mixtures of either caustic lime or oil, for the purpose of preventing moisture from getting into walls.

In building work it is a very serious problem to protect plaster properly from attacks of moisture, and a great deal of time must be devoted to the study of the subject before enough is known about the resisting ability of these materials, to determine whether or not they are being used properly.

Mr. Seaman. **Henry B. Seaman**, M. Am. Soc. C. E.—In speaking of the desirability of painting iron before embedding it in concrete, we should not lose sight of the fact that the present tendency is toward the use of steel-concrete construction; and, in that case, the steel should not be painted. The theory of the strength of this form of construction depends upon the adhesion of the concrete to the steel, and a coat of paint will prevent this adhesion. In this case the twisting or roughness of the rods is all that prevents them from slipping. The lack of adhesion of concrete to painted iron was illustrated recently where a portion of the side-wall of the New York Subway was moved bodily off its foundation, to make room for an extra track. The side-wall was composed of I-beams, with concrete arches between, and, when it was moved from the foundation support, portions of the concrete arches slid down the I-beams as though they had been lubricated.

The requirement that steel should be bright and clean before being painted may be carried to unreasonable extremes. If paint keeps the oxygen from the iron, it will prevent further corrosion, even though slightly rusted when the paint is applied. It is necessary, however, to clean the iron of all scale, whether of rust or other material, which might cause the paint to flake off. A first coat of paint would probably adhere better to iron with a dull surface, than if the iron were bright.

A number of years ago it was generally considered that the Phœnix column would rust inside; and as evidence of this condition the rusty

. Seaman. drain holes in the under side of horizontal chords of truss bridges were cited. In 1891, an examination of one of the columns of the Kinzua Viaduct was made, in order to ascertain the condition of its inside surface. The viaduct had been in service about nine years. One of the highest bents was selected, and a piece of iron, about 2 ins. in diameter, was cut from the underside of an inclined column, at a distance of about 2 ft. from the base. As the cutting was completed, the hard oxide-of-iron paint inside the column was broken along the edge of the cut and showed a clean bright surface on the iron. This demonstration needed no further argument, and indicated that iron would last indefinitely if kept from air and moisture. This fact would seem to be equally reassuring as to the life of "iron-skeleton" buildings constructed in recent years.

It is interesting to note the difference of opinion among various engineers as to the quantity of water desirable in mixing concrete. Some specifications require "water in such quantity that the concrete will not flush after being rammed," which may aid quick-setting, but can be fulfilled by a mixture almost dry. On the other hand, there is the requirement that it shall be floated, as mentioned by Mr. Hill, though some engineers consider that this would "drown" the cement. A medium between these two extremes is, perhaps, preferable, or, as General Gillmore used to say: "So much water shall be used as will just flush the surface of the concrete after thorough ramming." It is important, of course, that the concrete should be first thoroughly rammed solid against the steel surfaces.

Mr. Just. George A. Just, M. Am. Soc. C. E.—In so far as the question under discussion relates to the deterioration of structural steel when embedded in masonry, Mr. Miller's careful presentation of the conditions revealed by the demolition of the so-called "Pabst" Building is very interesting.

He is in error on one point, however. The structural frame did receive two coats of black (carbon) paint, one at the shops and a second coat during erection. This last coat was probably not applied with any greater care than is usual, under the rapid rate of construction which has now become characteristic for this class of buildings in New York City and elsewhere.

The limited life of skeleton buildings, by the early disintegration of the frames, because of their inaccessibility in the finished structure, which has been predicted so universally by laymen, is based on no knowledge or experience. Failure in this type is rather to be looked for from faulty design of frame or footings. It is gratifying, therefore, that the opportunity thus presented to inspect a frame once embedded in masonry shows it to be remarkably well preserved, considered as a whole. On the other hand, our deductions should be made guardedly, because of what is after all a short lapse of time.

PLATE XXXII.
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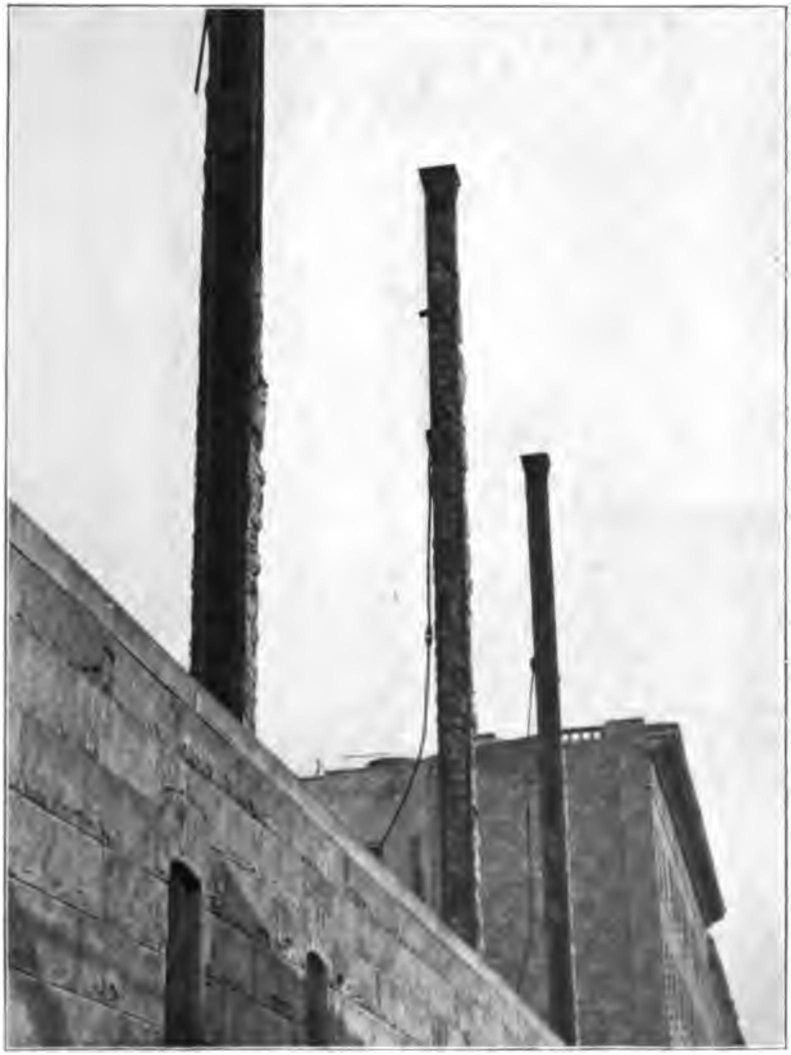
JUST ON PRESERVATION OF
MATERIALS OF CONSTRUCTION.



Columns of Seventy-first Regiment Armory.

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Just four years elapsed between the erection and the demolition of the structure. It was erected and painted in January, 1899. **Mr. Just.**

The use of particular kinds of paint, and the measure of protection which they afford, has been given undue prominence in the last few years. The question is not as important as the agent of the paint manufacturer would have us believe. He has occupied entirely too much of our time, and is to-day the *bête noire* of the structural engineer. For instance, the paint now used on the New York Elevated Railway structures, and which answers its purpose, is practically the same as that which has been used by the engineers of the road for the last ten years or more.*

It is true that the circular chimney stack, which was painted with another kind of paint, the red oxide of iron ordinarily used by local boiler shops, seemed badly rusted on the outside, in strong contrast to the well-preserved columns located close to the stack; but, as a matter of fact, this stack, on exposure, was found not to be corroded, but was well covered with pigment. It appears, however, that the heat in the stack had destroyed the oil. The pigment could be readily removed by the hand, and rapid corrosion set in soon after exposure. It would seem, therefore, that any conclusion as to the lack of protection afforded by the asbestos jacket is untenable. This emphasizes the important office of oil in paint, or rather, the less important part which the pigment takes.

The case under discussion also adds little or nothing to our knowledge as to how much protection was afforded by the paint used, beyond the contained oil, for it may be cited that the oil in the threads of the tie-rods and bolts was practically intact, and, where not broken by the nut, had formed a perfect protection against rust.

A further interesting development was the fact that the faces of the beam girders, stretching between the columns in the principal façade at some of the story levels, still retained an almost perfect coat of paint. Nor were they marked by any cement or mortar, but presented clean, black faces. It would appear, then, that at these points the front stone was not "backed" by brickwork, but was set away from the webs, and hence it may be concluded that, for limited periods, the steel, if only encased, is as fully protected as when embedded in brickwork.

While it may be granted that exposed iron and steel, when kept well painted, is protected against the deteriorating influence of rust, yet it is equally true that a sufficient number of instances have not been collated at this time to permit us to say the same of the painted steel frames embedded in the brick and stone walls of modern city structures, whose only excuse for existence is the use of walls of minimum thickness which they permit.

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* *Transactions*, Am. Soc. C. E., Vol. XXXIII, p. 535.

Mr. Just. Instances, throwing additional light on this phase of the question, therefore, should be welcome. A better illustration than the "Pabst" Building, if measured by time, is found in the case of the Seventy-first Regiment Armory in New York City. Built for more than twelve years, and destroyed by fire one year ago, eight riveted (Z-bar) columns, Plate XXXII, which supported the main roof, now extend exposed from the northerly and southerly walls in which they were embedded. These walls, now removed for the upper half of the length of the columns, permit inspection. The columns, inaccessible for more than ten years, were probably subjected to considerable heat during the fire, and have now been exposed to the weather for more than a year. Notwithstanding all this, they show no appreciable deterioration by rust, which, while general over the surface, is only superficial. Paint, apparently the red oxide of iron used almost exclusively at that period, shows, in patches, where the brick filling has fallen away. It remains especially good between the flanges at the top for short distances below the cap, where the brick filling seems to have been omitted. For the rest of their length these columns were well enclosed on all sides by the brick laid in close contact with the metal. Much of this brick filling is still in place on the exposed part of the columns, and, where it no longer exists, the original courses of the brickwork are still marked against the columns by stripes of mortar.

An interesting case of column corrosion was recently noted in the uprights supporting the roof garden of the "New York Theatre," at Forty-fifth Street and Broadway, in New York City (Plate XXXIII).

The load of the all-glass roof is brought to the top of these uprights by four intersecting trusses having curved lower chords. For decorative purposes, a part of each column, commencing some distance below the intersection of the curved chords with the column, and extending down to the floor line, was enclosed by two thicknesses of scenery canvas, which had been painted on both sides, and which was stretched over galvanized-wire cloth, which in turn was carried on furring strips consisting of small pieces of unpainted wood. This arrangement kept the envelope entirely clear of the column. Proposed alterations caused the removal of these jackets, when it was found that every column was entirely incrusted with rust scale, from the base plate of the column, under the floor, up to the point to which the jacket had extended. The unpainted wood furring and the galvanized wire were in excellent condition. Beyond this point, the columns, as also the intersecting overhead trusses, had received a second coat of paint. This coat was of lead with a light green pigment, which would indicate clearly even traces of rust. All this upper work, however, was rustless, and the paint in good condition. The lower and much rusted part of the column, it was plain, had never received any other

PLATE XXXIII.
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JUST ON PRESERVATION OF
MATERIALS OF CONSTRUCTION.

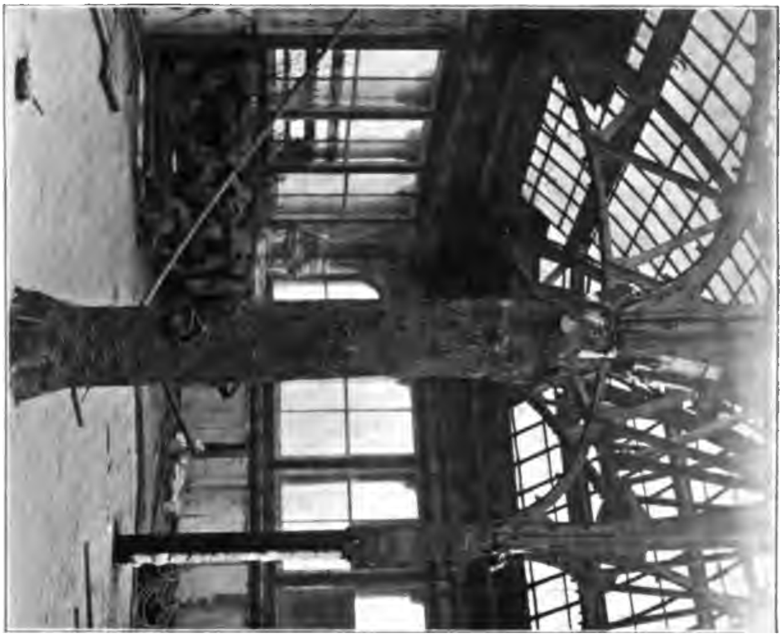

FIG. 1.—COLUMNS IN ROOF-GARDEN OF "NEW YORK THEATRE."

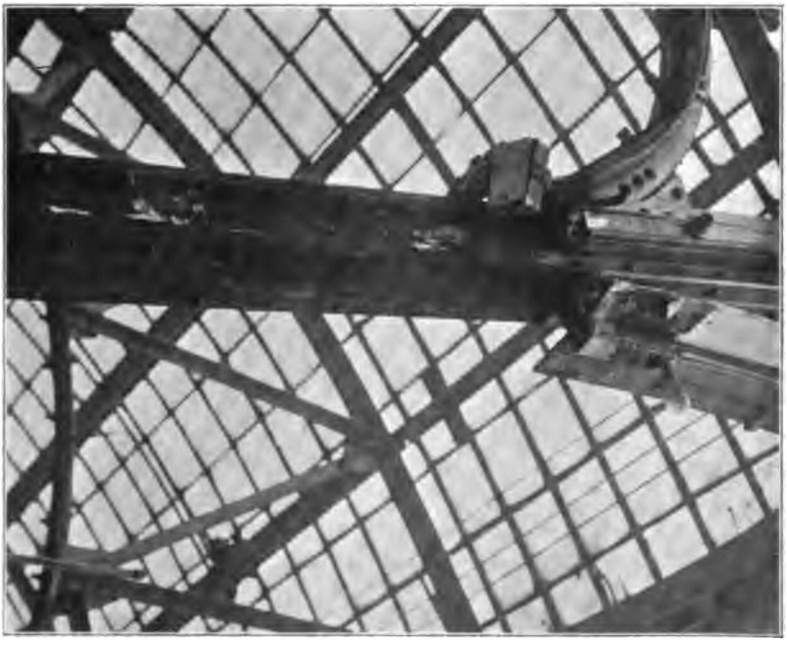

FIG. 2.—CORRODED COLUMN IN ROOF-GARDEN OF "NEW YORK THEATRE."

paint than the "mill" coat, and, judging from what little remained, was of the usual red-oxide variety. Mr. Just.

It was evident that the canvas jacket, for its entire length, prevented the rapid evaporation of the water of condensation from the roof, the flow of which the curved chords readily directed to and down each column. These columns have been in place about seven years.

In contradistinction to this case, it is interesting to note the condition of the interior surface of structural members, built up of shapes, in a manner to form closed sections. Twenty years ago, when the type of bridge popularly known as the "Phœnix" was first meeting serious criticism, because of its cast chord and post connections, and inaccessibility to the interior of these members for painting, a wreck of the Bell's Gap Bridge on the Delaware, Lackawanna and Western Railroad permitted a careful inspection. It was then found that the original coat of paint on the interior of the posts and chords was generally in a very good condition, notwithstanding their exposure since the wreck. This bridge when wrecked had been in place about eleven years.

Disks cut from similar columns, supporting a blast furnace, showed the original coat of paint on the interior surface to be almost perfect. These columns had been in place about fourteen years.

As to the condition of iron when buried in certain kinds of earth for long periods, Mr. Colin C. Simpson, of the Consolidated Gas Company of New York, says:

> "Of the two 'bar-shots' in my possession, the larger weighs about 20 lbs., and consists of a square wrought bar 10 ins. long, with cast-iron hemispherical heads. It was found in the Kingsbridge Road near Dyckman Street in 1893. The heads are almost in a condition as when cast, while the wrought connecting bar is only pitted superficially. The smaller 'bar-shot' is entirely hand-forged, and weighs 8 lbs. It was found in about the same locality in 1895. This shot is in a good condition throughout, and the hammer marks are still plainly to be discerned. Cannon balls of several sizes are so well preserved that some of them still retain the marks of the flask in which they were cast. The soil in which these shots were found is clean, dry and loamy."

He adds:

> "These missiles were fired, at the time of the American Revolution, from the British frigate *Pearl*, anchored in the Hudson River, off or near Dyckman Street, during the attack on Fort Washington, in November, 1776. They have lost practically no weight since their use 120 years ago."

The effect of lime and cement mortars, or of concrete, on embedded iron or steel, while well recognized, has received considerable attention in this discussion. In this connection it may be stated that the framers of the "Building Code," which at present regulates the construction of buildings in New York City, recognized the protection

Mr Just. which such materials afford to iron and steel, when embedded in them.

Section 25 of this code reads:

> "Where metal is incorporated in or forms a part of a foundation it shall be thoroughly protected from rust by paint, asphaltum, concrete, or by such materials and in such manner as may be approved by the Commissioner of Buildings."

What appears to be a more serious question than the corrosion of these metals, however, confronts those engineers who have been engaged in the construction of our tremendously large and expensive buildings. This is the recession of the water level, which is certainly taking place, at least, in the lower part of Manhattan Island. This recession, probably due in part, to the large increase in the number of "sky-scrapers," vaults and subways, must have exposed to decay many pile foundations where this method of founding was used.

In proof of this assertion it may be stated that, for a building recently proposed in that section of New York City, a pile foundation as originally designed had to be abandoned when, upon excavating the lot, it was found that the capping timbers and heads of the piles in the foundation of a large and prominent building adjoining on the west were no longer protected by water (see Fig. 1). The indications showed that a recession in the water level of at least 2 ft. had taken place, in the last ten or twelve years, or at the rate of 2 ins. per annum. Lest it be assumed that the piles under this building were originally not cut off at, or below, the water-line, it should be stated, on the authority of the engineer connected with the design and erection of the building immediately adjoining the proposed building on the east, that the concrete footings of that building were laid in water. This concrete base, of course, was also shown to be high and dry when the lot between the easterly and westerly buildings had been excavated to a sufficient depth.

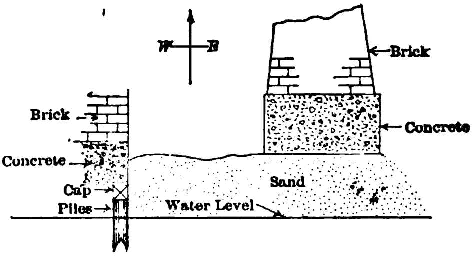

FIG. 1.

Mr. Gideon. A. GIDEON, Assoc. M. Am. Soc. C. E.—From the data submitted by those who have discussed the method of preserving steel, it would seem as though no hard and fast rule could be made as to whether or not structural steel embedded in concrete should be painted first; as it depends largely on the conditions to which the metal is to be subjected, and the functions it is to perform. Each individual case should receive the careful attention of the engineer, and, not unlike many other engineering problems, is a question of judgment, guided by theory and experience. Mr. Gideon.

In cases where the adhesion of the concrete to the steel is of great importance, and where there is no danger of the concrete cracking and breaking off or peeling away from the metal, the previous painting of the steel would seem to be unnecessary, as the concrete would be an ample protection against rust, and greater adhesion of the concrete to the metal could be thus secured.

On the other hand, where the concrete is likely to crack and break off, thus admitting air and moisture, it would certainly be of the utmost importance to paint it as carefully as possible, and thus prevent it from rusting.

FRANKLIN RIFFLE, M. Am. Soc. C. E. (by letter).—The preservation of the steel frames of modern high buildings from corrosion is a matter of vital importance, not only to the engineer and architect, but to the general public as well. That the subject is not given the attention it deserves is only too apparent to the most casual observer. Mr. Riffle.

The writer knows of three skeleton buildings, now in process of construction, in which the columns and beams were neither oiled nor painted from the time they left the rolls at the mill until they were riveted in place.

At this stage they were given two coats of paint. Although the steel was badly rusted, no attempt was made to remove the rust before painting. The presumption is that the painting was designed to prevent further corrosion; but it is the writer's experience that paint applied to a coating of rust soon cracks and crumbles when exposed to the influences which promote oxidation. For this reason it is generally conceded, by engineers and architects who are familiar with steel construction, that paint, to be effective, should be applied to the clean metal, preferably at the shop, before corrosion begins, or, if later, not until every vestige of rust is first removed.

The fact that steel skeletons cannot be inspected after the buildings are completed and occupied should induce those who are directly responsible for their design and construction to take every reasonable precaution to preserve the metal from any possibility of corrosion. In the light of present knowledge, it is a grave question whether, under any circumstances, an architect is justified in assuming that the conditions in the interior of a building are such as to render corrosion impossible or even improbable. Examples are not wanting to prove that wrought-iron columns and beams encased in brick masonry sometimes corrode badly when not otherwise protected. In most steel-skeleton buildings the outside columns and beams are protected from the

Mr. Riffle. weather only by a mere shell of stone or brick. Walls of this character cannot prevent moisture from penetrating to the steel frame and causing oxidation. The engineer or architect who has faith in protection of this sort is paving the way for trouble. The failure of a single column or beam at some future period may result in serious consequences, involving the loss of both life and property. With such possibilities confronting him, is the engineer or architect justified in neglecting to adopt such precautionary measures, to render his work both safe and durable, as the present knowledge of the subject warrants?

Without undertaking to discuss the relative merits of the various steel preservatives now in use, the writer desires to call attention to the preservative qualities of Portland cement. Not many months ago, Mr. Geo. W. Dickie, Manager of the Union Iron Works of San Francisco, stated to the writer that for many years, and with very satisfactory results, he had used Portland cement to protect iron and steel from corrosion. He stated that while recently repairing the iron hull of a ship he had occasion to remove a portion of the cement floor which had been laid some forty years before. The iron beneath the cement lining was found to be absolutely free from rust. For years it has been Mr. Dickie's practice to line the iron and steel water tanks of ships with Portland cement, applied as a wash, by means of a brush. He is quite pronounced in his belief that a protective coating of this character is a far more effective preventive of oxidation than most of the paints used for the purpose.

The fact that Mr. Dickie's experience as a ship builder has brought him in contact with the most active type of corrosion (that caused by salt water) adds to the value of his observations, and is certainly a strong plea for the use of Portland cement as a steel preservative.

Mr. North. **Edward P. North**, M. Am. Soc. C. E.—Speaking solely of wood pavements: The first wooden pavement of record in this country was laid in 1835, on Broadway, New York City; another piece, about 100 ft. long, was laid in William Street, New York City, during the next year. There is no record available of the time that this lasted, and possibly (if plank roads are excepted) there was no wooden pavement laid in this country from that time until about 1852 or 1853, when a wooden pavement, known as the Nicholson pavement, was laid on a bridge in Boston. For this pavement, a prepared bed of coarse sand was made, on which were laid 1-in. boards, swabbed with hot coal-tar on both sides, and on these boards blocks of pine, 3 ins. wide and 6 ins. high, were placed, after being dipped in hot coal-tar. A strip of wood, 1 in. x 2 ins., was placed between each row of blocks, and the interstices thus formed were filled with clean gravel and flushed full of hot coal-tar.

Afterward the same pavement was laid in Chicago, in 1857 or 1858.

From Chicago the use of this pavement spread over the West, and was brought to New York City in the time of Tweed. **Mr. North.**

Nearly all this pavement, with variants from it, rotted very fast. It was of untreated wood, and, further, was dipped in hot coal-tar, generally, but it was learned that with sufficient traffic such a wooden pavement would not rot before it wore out; that is to say, it would last six or eight years without showing any sign of dozing, if, during that time, it had sufficient traffic over it to wear it down from the original thickness to about 1¾ or 2 ins., when it commenced breaking up. But a pavement which was laid in places where the traffic was light very often commenced dozing in the course of two years, so that it was a shell at the end of five or six years.

These pavements, as laid in New York City, were so unsatisfactory, except one small piece in Fifth Avenue in the last of the seventies, that no wood pavement was laid until the end of 1895.

In England, the first pavement of record was laid in London in 1837. It was of beech. In London there was more or less continuous use of wood pavements, generally of hard wood, until about 1875, when patents were taken out by various persons, nearly all specifying that the wood should be treated with dead oil. In some the wood was saturated very thoroughly, and in others it was merely dipped in dead oil. A prejudice has grown up in England against treating pine or Baltic fir, which may be due to insufficient treatment, that of not saturating the wood fully.

Along in the last of the eighties, two specimens of wood grown on the southwest coast of Australia were brought to London for paving; one, the Karri wood, or *Eucalyptus diversicolor*, and the other the Jarrah wood, or *Eucalyptus marginata.* They are hard, reddish woods, with a rather peculiar odor, and it is said that iron driven into them will not rust. Pavements of these woods were laid in London with very great success, the claim being made that the Karri wood will last longer than the Jarrah. The Karri wood was brought over to this country and laid in New York City in the winter of 1895, on Twentieth Street, on the block between Fifth Avenue and Broadway, the pavement being accepted in January, 1896. It was laid on a concrete foundation. The bottoms of the blocks, which were 5 or 6 ins. high, were dipped about 2 ins. in a preparation of pitch, the composition of which was kept secret, the pitch being so hot and fluid that the coating was only about $\frac{1}{16}$ in. thick. The blocks were driven together as tightly as they could be, conveniently, and the top was covered with a very thin grout of fine sand and Portland cement. The west end of that pavement, toward Fifth Avenue, has been entirely wrecked by the construction of two large buildings with deep foundations. The eastern end, toward Broadway, has been left intact, and a large area of it has not been disturbed. That has now lasted a

Mr. North. few days more than seven years, as far as can be learned, entirely without repair, and it is in very good condition to-day, with the probability that at the end of four more years it will be in better condition than any granite pavement that has been laid in New York City. This is not a case of preserving wood, but of wood which preserves itself.

In regard to waterproofing brickwork, the attention of the members is called to a paper by the late William L. Dearborn, M. Am. Soc. C. E., read before this Society on May 4th, 1870, entitled "Experiments for Making Brick Masonry Impervious to Water, Tried on the Walls of the Back Bays of the Gate-Houses of the New Croton Reservoir in New York, and on the Brick Arch of High Bridge in 1863."*

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* *Transactions*, Am. Soc. C. E., Vol. I, p. 208.

Vol. XXIX. MARCH, 1903. No. 3.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

THE SANITARY DISPOSAL OF MUNICIPAL REFUSE.

An Informal Discussion.*

By Messrs. John McGaw Woodbury, Charles B. Ball, Charles H. Haswell and Rudolph Hering.

Presented at the Meetings of December 17th, 1902, and January 7th, 1903.

John McGaw Woodbury, Esq.†—In a large city, all sorts of wastes are found: Wastes of ashes, garbage, street sweepings and rubbish; the rubbish consisting of paper, broken-down sofas, discarded mattresses, old shoes, bureaus, washstands, broken crockery, dolls, toothbrushes, tin cans, rags, bottles. Every conceivable kind of waste is either found in the streets, or is put out of the houses, for the city to dispose of. What shall be done with it, has been and is still the question. Heretofore, in New York City, most of these wastes have been disposed of by the archaic method of dumping them into the sea. This is but an extension of the first idea of disposal, which was to throw such wastes into the street. Mr. Woodbury.

This idea of final disposition of refuse still exists in less civilized communities, particularly in tropical countries. It is practiced all through the West Indies, the only sewer being an open one running through the center of the street, into which it is the general custom to throw all wastes, including offal. They have but little ashes, and the carrion crow and turkey buzzard are the common scavengers.

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* Continued from the *Proceedings* for February, 1903.

† Commissioner of Street Cleaning, New York City.

Mr. Woodbury. In New York City, at present, the speaker happens to be the common scavenger. In Paris, in the time of Louis XI, there was an order appointing the hangman as the common scavenger, and giving him permission to remove dead horses and cattle from the streets. The world has made much progress since that time.

The problem of garbage disposal is a vexing one. By the reduction process, phosphates and grease are obtained. By the incineration of garbage it is claimed that heat can be obtained, and that this will generate power; but all experiments in New York City show that it takes fuel to burn the garbage in a sanitary manner. The question of cost is important. The best or most scientific and sanitary process is not the best financially.

Fig. 1, Plate XXXIV, is a photograph of a flat scow being unloaded in the ocean, outside of Sandy Hook. It shows clearly the quantity of flotsam, much of which will be distributed along the beaches a little later.

Fig. 2, Plate XXXIV, shows the Barney Dumper being unloaded at sea. It is a divided boat, or catamaran, and splits in the center, thus dropping its load. It is a great improvement over the flat scow.

The Delahanty Dumper, going to sea under its own steam, is shown in Fig. 1, Plate XXXV. It is also a catamaran, having pockets hung between the two hulls. Doors, hung by hinges in the bottom of these pockets, are opened and closed by steam power, thus discharging the refuse. By the use of this vessel the refuse is disposed of at a cost of about 19 cents per cubic yard.

One of the dumping boards of New York City, with two Barney Dumpers and a flat scow, is shown in Fig. 2, Plate XXXV. This method of loading scows is also very archaic, as the ashes and light refuse are blown about by the wind. At these dumping boards, and on the scows while being loaded, a number of men are always engaged in picking over or sorting the refuse and trimming the scows. Quite a revenue is obtained by allowing the material of value to be picked from the waste, besides the advantage of having the scows properly loaded.

The output of rubbish and ashes from New York City is about 2 000 000 cu. yds. per annum. If the rubbish is separated from the ashes, it means a great deal financially. At Riker's Island land valued at about $10 000 an acre is now being made by using the ashes as filling, which is certainly more economical than throwing this material into the sea and letting it go to absolute waste. Ashes make the best possible filling, and pack well behind the cribs, which are sunk on the mud bottom.

It is of the utmost importance that dumping at sea be stopped, not simply because it makes the beaches unsanitary and unsightly,

PLATE XXXIV.
PAPERS, AM. SOC. C. E.
MARCH, 1903.
WOODBURY ON SANITARY
DISPOSAL OF REFUSE.

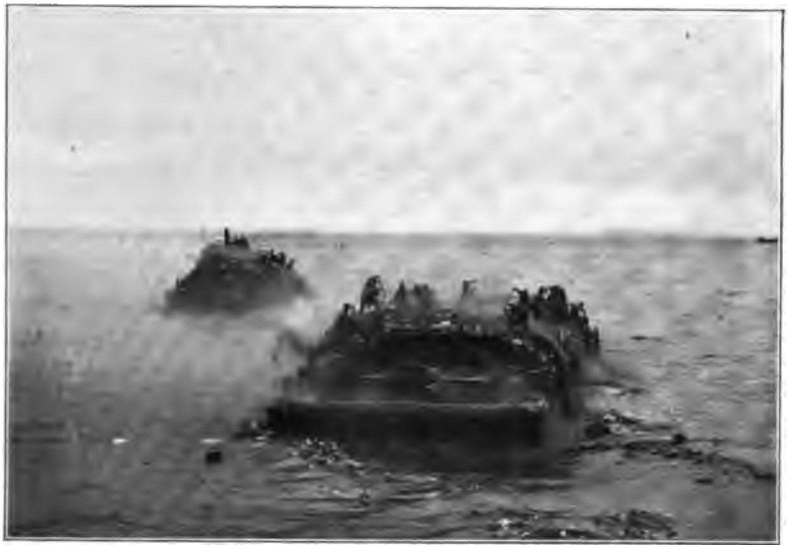

FIG. 1.—UNLOADING REFUSE FROM FLAT SCOW, OFF SANDY HOOK.

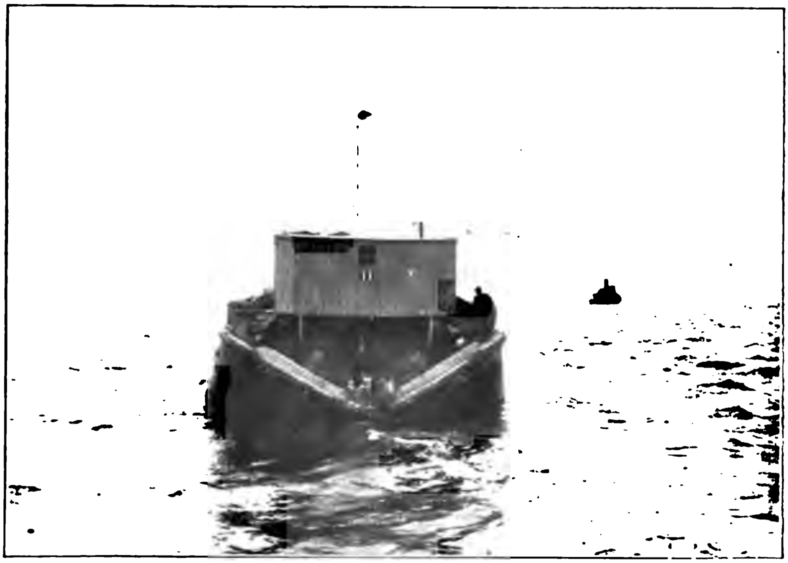

FIG. 2.—THE BARNEY DUMPER, BEING UNLOADED AT SEA.

but because it is a waste of valuable material. The separation of refuse is now in good condition. The quantity of garbage sent to the Sanitary Utilization Company in 1902 was 30 000 tons more than was ever sent in any previous year. This quantity of garbage has come mainly out of the ashes. The rubbish, also, is now kept separate in parts of the city, thus leaving the ashes almost a merchantable commodity. Mr. Woodbury.

For the disposal of rubbish Mr. Parsons has designed the incinerator on the pier at Forty-seventh Street and North River. It is burning about 60 loads of 5 yds. each, or about 30 tons in eight hours, every day. This rubbish consists of excelsior, mattresses, trunks, barrels, boxes, chairs, sofas, paper, rags, etc. These, in burning, produce sufficient heat to make steam in boilers which will furnish power to run a belt-conveyer, now being constructed, which will be used for sorting the material. The surplus power will be used for lighting, for the elevator, for a traveling runway to the dumping board for loaded trucks, and possibly there will be some power which can be sold.

The City of New York now receives $110 000 a year for the privilege of sorting, and when greater facilities are given the sorters, as by the conveyer mentioned, a much larger sum will be realized.

Aside from the sanitary handling of the refuse, 63 acres of land have been made at Riker's Island, which is equivalent to $630 000; the privilege of picking over the refuse has been sold for $110 000 for the year; and the utilization of power from burning the non-marketable refuse will bring the total income up to about $900 000 a year. In this way the city's wastes become a source of revenue which will help materially in cleaning the streets.

Charles B. Ball, M. Am. Soc. C. E.—There are two inquiries which seem to be pertinent to this subject. One is the question as to how far it is safe and desirable to use street sweepings as material for filling. The second relates to precautions to be observed in handling builders' refuse resulting from the demolition of dwellings which have been for a long time in an infected condition. Mr. Ball.

The Use of Street Sweepings for Filling.

The division of municipal refuse into four classes, as used by Mr. Hering:

I.—Ashes;
II.—Street sweepings;
III.—Dry rubbish;
IV.—Kitchen garbage;

is a convenient one for the present purpose. It should be remembered that only in exceptional cases are street sweepings collected sepa-

Mr. Ball. rately, the usual method being to mix them, as found convenient, with any other class of refuse.

Premises.—To make clear the proposition advanced by the speaker, let it be assumed, at the outset, that kitchen garbage alone ought not to be used as material for filling low grounds, and that all mixtures of garbage with either ashes, street sweepings or dry rubbish are objectionable for this use to the degree in which they contain the more putrescible ingredients; also, that under some conditions ashes, and sometimes dry rubbish, may be utilized in this manner without danger.

The inquiry, then, is thus formulated: Whether street sweepings alone, or mixtures with ashes or dry rubbish, into which they enter as a principal element, are not undesirable materials for filling in low lands, parks and streets? It seems that this use of sweepings ought to be questioned, for three reasons: First, because of the considerable percentage of organic matter which they contain; second, because of the disease germs which are present in them; third, because of their objectionable physical qualities.

Prevalence of this Method of Disposition.—In connection with the general statements in Mr. Hering's opening discussion, that the use of sweepings for filling low land is a common one, certain data in *The Engineering Record* of November 29th, 1890, are of value. In a tabulated statement giving returns from seventy-eight cities and towns, as to the method of disposition of street dirt, which, doubtless, includes rubbish as well as sweepings, it is stated that fifty-four of these municipalities (69%) used such materials "for filling low places and private lands, or for grading streets and park grounds."

From the more comprehensive statement summarized by A. Prescott Folwell,* M. Am. Soc. C. E., from the detailed reports obtained for the "Municipal Year Book for 1902," it is learned that 741 of the cities and towns having a population in excess of 3 000 report that street sweepings are used for filling. This number is 76% of those that report upon the method of disposal. It may also be noted that the Department of Street Cleaning of the City of New York advertises that:

> "Persons having lands or places in the vicinity of New York Bay to fill in, can procure, free of charge, material for that purpose—ashes, street sweepings, etc.—collected by the Department of Street Cleaning."

Quantity.—Although few statistics are obtainable as to the total quantity of street sweepings handled by municipal authorities, the ratio which the refuse thus classified bears to the total quantity collected is ascertainable for some of the larger cities, as well as the quantities of sweepings collected by them.

In a table prepared for the Advisory Commission to Mayor Hugh J. Grant, and published in its report in 1891, the percentage distribu-

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* *Engineering News*, November 20th, 1902.

PLATE XXXV.
PAPERS, AM. SOC. C. E.
MARCH, 1903.
WOODBURY ON SANITARY
DISPOSAL OF REFUSE.

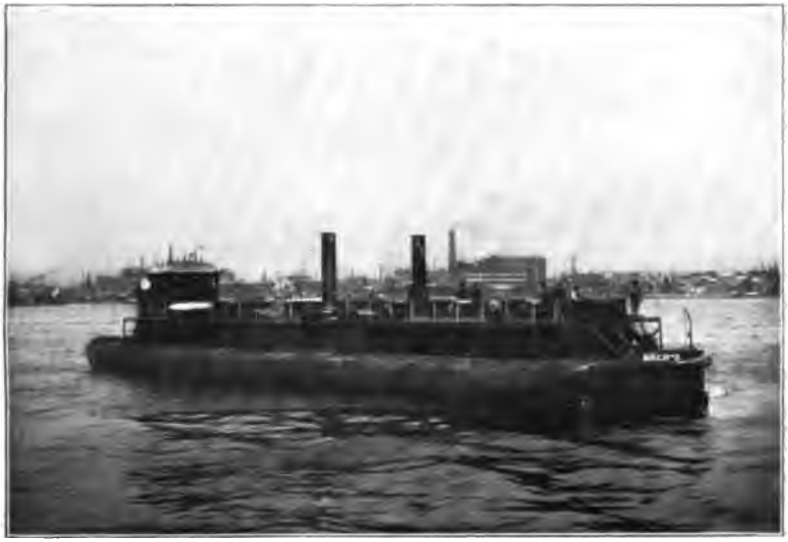

FIG. 1.—THE DELAHANTY DUMPER.

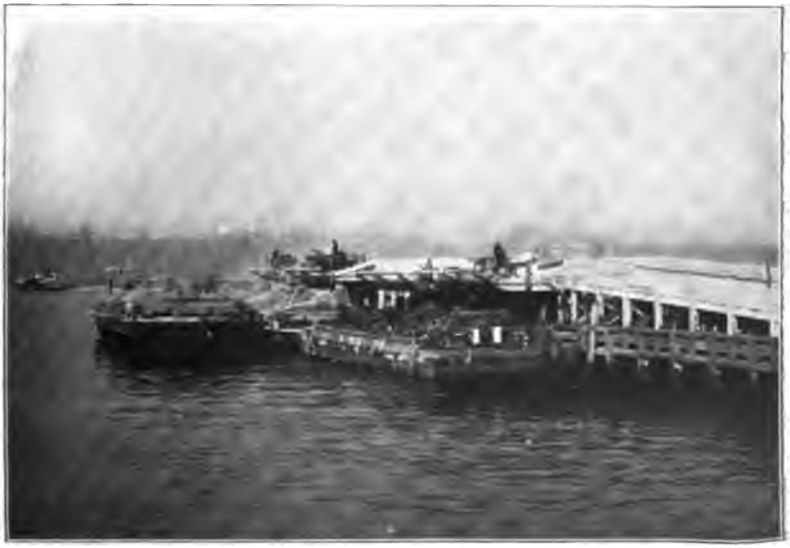

FIG. 2.—LOADING SCOWS WITH REFUSE.

tion of the refuse collected in New York City in the years 1882–1890, is stated to be: Mr. Ball.

Ashes	about 62 per cent.
Garbage	12 "
Ice and snow	2 "
Street sweepings	24 "

The statement made by Mr. Parsons is that the distribution by volume is:

Ashes	57 per cent.
Rubbish	25 "
Garbage	18 "

There appears to be no difficulty in harmonizing these statements, it being understood that street sweepings and rubbish are included in a single item, and that the garbage constituent may often include many kinds of waste which, in a strict analysis, should be classified as rubbish rather than garbage. The latter table, by Mr. Parsons, showing the *per capita* distribution of the refuse in Greater New York, gives about 18% by weight of street sweepings. From these, and other less complete data, it would seem probable that 20% of the total amount of refuse well represents the proportion of such material in cities where the collection is made in well-defined classes, or that, at all events, such a percentage is not too large.

The report of the operations of the Department of Street Cleaning for the year 1900, which is the latest obtainable, states that it collected from all of Greater New York, 2 307 594 cartloads of "ashes, street sweepings and other refuse," apart from the item of garbage, separately named.

Composition of Sweepings.—The composition of street sweepings varies greatly with the character of the pavements from which they are gathered, with the method of sweeping—whether by hand or machine—and with the effectiveness of the separate collections of dry rubbish, such as dust, leaves, rags, paper, metal, old leather, straw, wood, glass, etc.

Organic Constituents.—It is obvious that sweepings from smooth, impervious, elastic pavements will contain much greater percentages of organic matter than such as are collected from macadam or rough stone pavements.

The limits indicated by Baumeister* are 4% for macadam pavements to 23% for stone pavements, and 60% for wooden pavements.

An analysis of street dirt made in 1874 by Professor Edwin Waller, for the Health Department of the City of New York, gave, for an average of thirteen samples:

Water	3.032 per cent.
Organic and volatile matters	28.454 "
Nitrogen	0.369 "
Mineral	68.514 "

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* "Cleaning and Sewerage of Cities," 1891 edition, p. 177.

Mr. Ball. There appears to be no evidence to determine whether rubbish was or was not included in the samples for this analysis.

Examinations of the percentage of moisture, ash and organic and volatile constituents found in samples of ashes, sewer dirt, street sweepings and rubbish collected in New York City on two different dates, March 14th and May 1st, 1902, give percentages of the organic constituents varying from 17.86 to 40.70. The average of five analyses for each of the above dates was 26.31% of organic and volatile matters. The samples were collected by the skilled chemist who made the analysis, and garbage was excluded.

The prevalence, at the present date, of sheet-asphalt for street surfaces, as well as the constant increase in the ratio of paved to unpaved streets, would be likely to indicate that a higher percentage of organic matter is common, and it would seem that an estimated percentage of organic matter in sweepings at least as high as 35% would be justified.

Rubbish Constituents.—If street-cleaning machines are used instead of hand-sweeping methods, the resulting refuse will contain a smaller quantity of miscellaneous rubbish, as the sweepers and shovelers in the latter case collect from the gutters various articles of small dry rubbish which the machines do not touch. Most of these materials, such as leaves, paper, straw and hay, are light and combustible, but considerable quantities of waste metals, glass, crockery, plaster, etc., are heavy and incombustible.

Germ Constituents.—In addition to the tuberculosis germs noted by Mr. Hering as being abundant in street dirt, the bacilli of diphtheria are by no means uncommon, and typhoid fever germs are sometimes found.

A series of experiments was conducted by the Street-Cleaning Department of the City of New York in August, 1902, by exposing Agar plates, at the curb level and 6 ft. above, in various locations distributed over the city, and noting the number of colonies of bacilli developed during a stated period. The isolation of specific pathogenic germs was not attempted, to any considerable extent, the object being to determine the varied effect of different kinds of traffic in distributing the bacteria in air; but a maximum of 30 colonies per inch-minute was found in the east-side tenement district, and a minimum of 0.06 colony for a suburban street in the Bronx.

The important question respecting the danger from these bacilli is that of their viability.

It is now well known that the tubercule bacillus retains its life properties for long periods when dry, but it is not so well demonstrated that it is dangerous when in a moist condition, such as would occur most frequently beneath the surface of a fill. Respecting the life of the typhoid and diphtheria bacilli, there appears to be no doubt that these are perpetuated in damp surroundings.

Professor Charles Harrington, in his "Manual of Practical Hygiene" (1901), discussing the function of the air as a carrier of infection (pages 226–230), summarizes the extensive researches of Dr. Eduardo Germano on the permanence of typhoid with the statement that "this germ as well as that of diphtheria can live for a long time in moist surroundings."

G. Lister Sutcliffe, in an introductory chapter in his "Sanitary Fittings and Plumbing" (1901), says:

> "Dr. Sidney Martin's experiments with the typhoid bacillus, for example, prove that it soon dies in 'virgin' soils, whether these are sandy or peaty, but that it rapidly multiplies in moist sterilized samples of soils from gardens and other cultivated places, and retains its viability and vegetative properties for months and perhaps years. Moist sterilized soil which had been impregnated with the typhoid bacillus was found to contain the bacillus at the end of 450 days. The soil was then naturally dried for 49 days, till it 'could be readily powdered into a fine dust;' the bacillus was still there.
>
> * * * * * * * *
>
> "The lessons to be learnt from these and other investigations are that some pathogenic organisms are not by any means so short lived as is commonly supposed, that they may spread rapidly under suitable conditions, and that they may exist for a considerable time even in dust so dry as to be blown about by the wind."

Physical Characteristics.—It is evident that the physical qualities of permanence and stability, required in ground to be used for foundations of structures, or even for the sub-surface of streets and parks, are lacking in street sweepings, owing to the considerable quantity of organic matter and light combustible material contained.

Conclusions.—That the opinions expressed by the speaker are not altogether new, is shown by a paper on "City Scavengering at Boston," read by Eliot C. Clarke, M. Am. Soc. C. E., at the meeting of the Metropolitan Public Health Association in Nashville, Tenn., on November 18th, 1879. The work of scavengering is here classified as constituting four parts:

1.—Removal of offal;
2.—Removal of ashes and house dirt;
3.—Cleaning of streets and street basins;
4.—Cleaning of privy vaults and cesspools.

Under the second division of his subject, Mr. Clarke writes:

> "A large part of Boston being very low land, there is great temptation to use this refuse (ashes and house dirt), in the place of earth filling, and such is its usual disposition. If the ashes were perfectly free from admixture with other substances, it would form suitable filling for most purposes, but it is not so."

He then explains the attempts to keep out objectionable rubbish, and, in the following statement, summarizes the failure to accomplish this:

> "On an average, nearly one-third of each cart-load of so-called ashes consists of other refuse. Portions of this refuse are harmless

Mr. Ball. enough, as, for instance, broken glass, crockery, plaster, old iron and tinware, but other portions entirely destroy the suitability for filling, such as bones, hair, leather, rubber, paper, pieces of cloth and carpeting, old baskets, and, in short, any vegetable or animal matters liable to decompose. The ashes and house dirt are used to grade streets and parks belonging to the city, and private lands, when desired or permitted by the owner. In a few cases a small sum is paid to the city for the filling. It is evident that the presence of the refuse house dirt renders ashes undesirable for street building, as the matter, as a whole, compacts very slowly, and continues to settle for years. If the surface be paved or covered with gravel, there will probably be no smell; but digging trenches for laying gas and water pipes, sewers and drains, will be an offensive operation for a number of years, since organic matters, kept from a free supply of oxygen, decompose slowly.

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"It is probably a serious mistake to dump house dirt on land which is to be built upon. It is true that the organic matter mixed with the ashes must in time disappear; but how soon, it is impossible to say. Excavations made in Boston in land filled from city carts ten years previous have disclosed remnants of organic matter, and the process of decomposition is still going on. The risk in living over such land may be slight, but, however slight, it is a risk of disease and death."

In considering the third division of the subject, he writes:

"Forty-eight thousand and fifty-nine (48 059) cart-loads of dirt (street sweepings) of 40 cu. ft. each, were collected during the past year (1878?), and were disposed of in the same manner as ashes and house dirt, by being used to fill land for streets, parks and dwelling lots. The street dirt is of a rather uniform character, consisting of earth, road detritus, fragments of wood, leaves, paper, soot, hair, etc. Under exceptional conditions, from well-paved streets in the heart of the city, a load is sometimes obtained of sufficient manurial value to fetch a small price for use on land, but this is seldom. It is a manifestly unfit substance for filling, both from an engineering and from a sanitary point of view; but what else to do with it is a problem yet unsolved."

To the speaker, the solution appears to be a clear one, in view of the statement by Mr. Parsons, that "rubbish collections are very combustible, as are also street sweepings." The conclusion appears to be incontestable that street sweepings may and should be burned, irrespective of the question whether they can or can not be made to assist in disposing of the more objectionable garbage.

THE DEMOLITION OF INFECTED DWELLINGS.

It has been recognized for some years by students of sanitary science that human habitations in which filthy conditions prevail for a long time become so infected with disease germs that no cure can be effected. Although the recent methods of disinfection by formaldehyde gas are to a degree effective, it seems questionable whether even those will render safe for habitation a dwelling which has for a long time been permeated with disease and filth.

Danger of Infection.—The report of the Tenement House Committee of 1894 (usually called the Gilder Commission, from R. W. Gilder, its Chairman), makes a brief reference to their conclusions in this regard, as follows: Mr. Ball.

"It is a well-known fact that human dwellings, by prolonged occupation, become so saturated with the bodily emanations of those who have lived in them, sick and well, as to be less healthy than newer houses. It has often been proposed to construct hospitals of flimsy and inexpensive material, after the manner of a temporary shelter, and destroy them by fire every few years, to be replaced with new ones.

"This result of prolonged human occupancy is made worse in this city by the rapidity with which the character of the population in the lower parts of the city has changed, and the fact that houses built as private dwellings are not fitted to serve as tenements, either in respect to light, ventilation, water supply, privacy or facilities for cleanliness."

Respecting the fact of tuberculosis infection in old houses, there is no higher authority than Arthur R. Guerard, M. D., of New York City. In a paper presented to the Tenement House Commission, November 16th, 1900, treating of "The Relation of Tuberculosis to the Tenement House Problem," he says:

"It has been repeatedly observed that some houses in overcrowded districts after a time seem to become permanently infected with tuberculosis, as evidenced by a repetition of cases of the disease. * * * It is easy to understand how the permanent infection of premises may occur when one considers that the sputum of consumptives, which frequently contains a countless number of virulent tubercle bacilli, is often carelessly expectorated on the floor and elsewhere in dwellings, where it dries and is converted into dust, thus getting into cracks in the woodwork, in the papering, etc., whence it is later inhaled into the lungs by others. Such tuberculous dust has been found by experiment to remain virulent and infectious for months and even years after it was deposited in rooms which were not thoroughly disinfected and renovated; and where this dust is allowed to accumulate for a length of time it may be impossible to disinfect and renovate the premises without practically rebuilding them. These premises then become permanently infected."

John F. J. Sykes, M. D., in his recent book on Public Health and Housing, thus refers (pages 82 and 83) to the dangers of infection:

"Miquel, Emmerich, Carnelly, Haldane, Anderson, Johnstone and other observers and experimenters have shown that with the increasing use and age of a dwelling-house the walls and spaces beneath floors become liable to harbour micro-organisms to an increasing degree. The more the surfaces, especially the floors and walls of a house, become worn and defective, the better lodgment they present for the accumulation of organic matter—the nidus of micro-organisms—and the less attention paid to repair and redecoration, the more unhealthy the influence of the house becomes.

"All these experiments and observations indicate the necessity for such construction, maintenance, and usage as best conduce to the

Mr. Ball. cleanliness and purity of the air in and around dwelling-houses, in order not only to prevent disease, but also to prevent the loss of that vitality, vigour, and energy which cannot easily be measured by experiments or by statistics."

The conclusions of these various investigators as to the danger in the use of such dwellings, appear to the speaker to justify reasonable precautions in their demolition, and in the handling of the materials, both the valuable and the useless, resulting from this tearing down.

The number of buildings for which demolition permits were issued in 1902 by the Bureau of Buildings, Borough of Manhattan, Greater New York, was 1 622. This number, it is well understood, does not represent all the buildings demolished, as a small proportion is torn down without the formality of a permit. If this list is examined by anyone conversant with the city, he will note, from the street locations, that certain of these demolished dwellings are very old buildings in tenement districts, and in some cases such as were not constructed originally for tenement purposes. A search of the records of these buildings will show that they are infected with disease, and have been for a long period in unclean condition.

Present Method of Demolition.—The present method of demolition results in the removal, for fuel purposes, by the poor of the neighborhood, of the smaller portions of the wooden floors, casings, roof, etc., which are then stored in the adjoining cellars. It results from this that a building infected with disease germs, filth and vermin, may readily disperse these dangerous elements in the vicinity.

The only supervision of a sanitary nature over the practice of demolition in New York City at the present time is the requirement by the Department of Health that frequent sprinkling with water should be given to the walls as they are torn down, in order to avoid objectionable dust.

Desirable Precautions.—It would seem to the speaker desirable to examine all buildings, about to be demolished, as to their sanitary condition, and, if this is found to be at all doubtful, to observe the following precautions in their destruction: First, that the building should be kept constantly wet with a disinfecting solution as the work of tearing down proceeds. From what has been stated already, it is evident that the old paper on walls and ceilings, the plaster of walls, and the woodwork of the floors, doors and trim of the rooms and halls are the elements of danger. These should be sprayed thoroughly at the commencement of the work, and kept wet. The Building Code of the City of New York requires the demolition of buildings to be carried on story by story, and the systematic execution of the work as indicated herein would be facilitated by the adoption of this rule in all cases.

Second, that no combustible material should be distributed in the neighborhood, but that it should all be removed, and that which is valuable for fuel only thus used under conditions which would prevent the danger of contagion. The old paper, lath, floors, doors and trim of the rooms should be burned at some locality remote from any residence, and, by the use of simple gratings, will furnish fuel for the incineration of much of the light refuse. Mr. Ball.

Third, that any portions of the structure which are suitable for use in new buildings should not be thus used without having been subjected to suitable disinfecting processes.

Fourth, that, during the process of further excavation of the site, the soil removed should be examined as to polluting matters, and, if found to contain such, it should be treated with disinfectants. The actual demolition of old tenements in New York City, with the excavations for cellars of new buildings, shows that, where school sinks and earthenware house drains have existed, there is an extended saturation of the soil. The removal and proper treatment of this saturated soil is a matter of great importance.

Fifth, that all non-combustible waste refuse should be kept under supervision, as to the method of disposal. Where it is impracticable to treat any waste material by some process of sterilization, the disposal should be at some locality not likely to be used, even in the remote future, for residence or business purposes.

Chas. H. Haswell, M. Am. Soc. C. E. (by letter).—The introduction of water into towns and cities for domestic and public services, other than that obtained from public and private wells, involves the laying of pipes for its reception and transmission, and of sewers for its discharge in combination with the excrementitious matter of their residents and animals, the filth of hospitals, households, slaughter-houses, stables, manufactories, tanneries, street washings, etc. The resultant of this flow is the pollution of the earth or water over or into which it is discharged. Mr. Haswell.

The disposal of crude sewage and its treatment, the mitigating of its septic elements, its sanitary, useful and effective disposal, combined with the resulting pollution of the rivers into which it is discharged, and the insanitary effects thereof, is becoming a subject so important, as relates to the existence and duration of human and animal life, that it imperatively demands immediate consideration and action. It is of more national importance than the aggregation of all the financial and political questions of the time; yet, with the exception of the consideration and report of the St. Louis Commission on the Chicago Drainage Canal, and possibly some other isolated cases, it is criminally neglected.

Primary Disposal.—In internal villages or small towns it is customary and quite practical to mix the excreta with earth, bear it beyond the residences of inhabitants, and use it for fertilization, or deposit it in masses and cover it with earth. In the more populous towns of Europe, trenches are excavated and filled, the ground selected being

Mr. Haswell. suitable for infiltration of the fluids of the sewage reservoirs and cesspools, and being located at a proper distance from residences. When filled, these trenches are covered with earth, the surface of their contents, meanwhile, being exposed to evaporation, and their whole contents to infiltration (their masonry being open-jointed); but when the earth in which they are placed is clay, wet or saturated, or is contiguous to a stream of potable water, they are constructed with close joints, and, periodically, their contents are pumped out and distributed for fertilization.

Treatment.—In order to mitigate the noxious exhalations of crude sewage, it is, in some instances, delivered into tanks, reservoirs or coke-beds, for aeration, subsidence, filtration and oxidation.

Chemical Purification and Precipitation.—Chemical purification is effected by a strong mixture of lime, salts, sulphur, oxidizing compounds, etc., with the crude sewage. Iron and aluminum salts, if followed by lime, give a purified effluent.* Precipitation is effected by the use of lime in solution, and by sulphate of alumina. In populous towns and cities, any like treatment of their sewage, in consequence of its volume, is wholly impracticable.

Surface Precipitation.—This involves the occupation of a large area of land, it being officially estimated at one acre for every hundred of human inhabitants.

In the course of purification, oxidation is an essential portion of the changes through which sewage has to pass. Sedimentation or subsidence of the solid and dense material of sewage is claimed to arrest pollution; if so, the effect is retroactive, as it would result in the gradual filling up of the bed of the river, by the formation of foul and noxious shoals. The natural purification of water, to the very slight extent to which it is attainable, is effected by the combination of ammonia, arising from the mixture of decomposed animal matter, with the oxygen of the atmosphere.

Filtration.—In order to arrest bacteria and organic matter by this process, sewage is delivered into reservoirs and subjected to the absorbent capacity of coke and sand; which operation involves the frequent cleaning or replacing of these materials, as their absorbent capacity will soon become inoperative on account of the arrest of the dense particles of the sewage.

Infiltration.—Infiltration is classed by Rideal under three divisions as Broad, Intermittent, and Mixed.

Broad.—In broad infiltration, the sewage is distributed over large surfaces of agricultural land, or sewage farms, as they are termed, on which it is purified. This method involves the occupation of very large areas of land, officially estimated, like that of precipitation, at one acre per hundred of population.

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* Samuel Rideal, D. Sc., London. John Wiley & Sons, N. Y.

Mr. Haswell.

Intermittent.—This is effected by the deposit of sewage at short intervals of time, on an area of porous earth as restricted as will absorb it, but making the products of vegetation of secondary importance.

Mixed.—In the mixed system, the sewage is first purified by sedimentation or by chemical means. The efficiency of this operation depends wholly upon the character of the soil, as to its porosity and freedom from water, saturation, clay, peat, or conglomerated gravel. The Local Government Board of England prescribes for stiff clay one acre for every twenty-five human inhabitants, and for loamy gravel one acre for every one hundred.

Cremation.—Cremation is effected by the evaporation and the combustion of the crude sewage at a very high temperature, a forced draught in the furnace, and a very high chimney to dispel the noxious effluvia of the combustion. In the operation of some furnaces in England, it was essayed to prove that sludge (precipitated and dense sewage), both remuneratively and without offence, could be incinerated, and that the coke produced paid for the operation. It was found, however, that the agricultural value of the residuum was so much impaired that it could not be disposed of profitably for that purpose. The evaporation of the liquid, and the combustion of the sludge requires the consumption of some fuel. When the sludge is submitted to a filtering pressure, an average of 7.74 tons (2 240 lbs.) per million United States gallons of crude sewage is obtained. At Southampton, England, it was essayed to burn sludge remuneratively, and without noxious results. The combustion of coal was first used to try it, the ammonia evolved was collected and the volatile matter was passed through the fire. It was claimed that the value of the coke produced paid for the cost and expenses, and that the net cost of the combustion and incineration was inconsiderable. In support of this operation, it is to be considered that even where sewage is discharged into bays upon the sea coast and below the confluence of the tidal and river flows, the velocity of the ebb tide is not wholly effective in transporting it to the ocean, as it will subside in slack water, and in the basins (locally and erroneously termed slips) formed by the projection of piers, thus creating noxious exhalations, and causing frequent dredging and the transportation of their contents to the ocean.

Fluid Discharge and River Pollution.—Where towns and cities are located on a long river, and above the extreme line of confluence and commixture of its water with the tidal water of the ocean, as some on the Hudson, Delaware and Connecticut in the East, and on the Ohio, Illinois, Mississippi and Missouri in the West, the pollution of the water by the discharge of crude sewage into it is increased progressively by the discharge from other and adjoining towns, but somewhat mitigated by the gradual addition of water from tributary streams (which, Mr. Haswell. however, will eventually become polluted in like manner), down to the point of its confluence with the water of the ocean.

Effect of Pollution.—It is generally, if not universally, claimed that foul or polluted water purifies itself, and, in support of this claim, tests and observations have been made. Thus, the Massachusetts Board of Health deduced that if the crude sewage was less than 0.0077 ($\frac{1}{130}$) of the water of a river into which it was discharged it would not affect the water objectionably. In other words, it is advanced that if one measure of crude sewage is mixed with 129 measures of river water in its normal condition it would yet be potable, notwithstanding that its septic or putrefying quality would not be negatived or eliminated. Further, an investigator in Europe has declared that if the crude sewage does not exceed 0 066 ($\frac{1}{16}$) or 6.7% of the river water, when it flows with velocity equal to that of the sewage, it would not affect the potable quality of the water; notwithstanding that, in addition thereto, all streams and rivers are polluted more or less by the rain washings from farmyards, roads, decayed vegetable matter and the putrefaction of dead animals.

As to the distance in which crude sewage discharged into a flowing river will become innocuous by the alleged self-purification of the water, authorities differ, as one puts it at 25 miles and another at 200. The desirability of assigning any general distance, assuming it practicable to do so, is negatived by the point of location at which any putrescent matter was present. Thus, a putrefying carcass of an animal, by its gravity (for instance, that of a dog with a weight attached to it), may remain at the bottom of a river. Over this the water would flow, and receive putrescent matter from it for a long time.

While it is conceded that pure water is only chemically obtained, in a laboratory, natural water is acceptable for domestic requirements, provided it is free from noxious matter, and is not offensive to taste or injurious to health and commercial requirements.

Notwithstanding the popular declaration that even crude sewage, discharged in flowing water, will, when mixed with it, in various assumed and empirical proportions and assigned distances of flow, become potable, a knowledge of the various impurities of such polluted water is not pleasing to reflection. The riparian inhabitants of the river into which the sewage of a populous city flows are passively subjected to the drinking of its water of pollution, yet, at the same time, they will consider the presence of any, even slight, impurity in their other fluids or foods, as milk, mineral waters, flour, meats, fruits, etc., as objectionable and not to be submitted to passively. As to the "self-purification" of water, it is difficult to manifest how the many and various chemical, vegetable and animal pollutions can be eliminated from polluted water by any process, physical or chemical, and unless they are eliminated, the assertion that water will purify itself

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is a common and grievous error, and, despite the claims of chemists and scientists of all grades, they are challenged to manifest in what manner, chemical or self-acting, water infused with excrementitious matter, the discharge of tanneries and slaughter-houses, paint, ink and glue factories, hospitals of all kinds, dead bodies of men, animals and fish, can be made acceptably palatable. A whole is an aggregation of its parts, and if a volume of foreign or offensive matter, however small, is introduced into pure water, its purity is negatived.

Insanitary Effects.—Living animals cannot retain health while the discharged products of their vital action are permitted to be retained about them, and when they are confined in that condition death gradually ensues. The result of a sanitary disposal of fluids is illustrated in the improvement of the health of towns by the reduction of their death rate. An instance is the City of Leeds, England, where, in twenty years, the death rate was reduced from 28 to 18 per thousand of its inhabitants.

In towns and cities where infiltration is wholly depended upon for the disposal of sewage, the soil becomes contaminated with fæcal matter, which, undergoing but little oxidation and in combination with the periodical cleaning out of the cess-pools or reservoirs, renders the exhalations therefrom both noxiously offensive and insanitary. In the country and in some small towns it is customary to avail of streams over which to set privies, and when the streams are sluggish the fæcal matter will subside in its flow and pollute the earth to an extent affecting its sanitary condition.

Reviewing, then, the elements submitted, it is presented:

1st.—That for internal villages and small towns, sewage can be readily disposed of by infiltration in and the fertilization of the adjoining soil.

2d.—That for similarly situated and larger towns and small cities, while the sewage can be infiltrated to a serviceable extent and the solid portion used for fertilization, yet the area of soil required for effectual operation is so great as to render this method generally, if not wholly, impracticable.

3d.—That from all locations, from villages to populous cities, on tidal rivers or sea coasts, up to the clearly defined limits of the tidal flow or confluence with the fresh-water flow, their sewage may be discharged directly in its crude condition, as instanced in the seabound cities of Boston, New York, etc., Burlington on the Delaware, etc.

4th.—That if the discharge of sewage, crude or treated, into our rivers is continued, it will wholly arrest them from being resorted to for the supply of potable water, and supplies must be obtained from the ponds and lakes with which our country abounds. Animal life cannot exist in polluted water, and the cost of arresting its pollution, Mr. Haswell. in view of its result, is not to be considered. As the health of our people is of primary importance, the emergency must be faced.

5th.—That to draw upon the waters of Lake Michigan and its northern tributaries for the service of the Chicago Drainage Canal and the mitigation of its pollution of the rivers into which it is discharged, and by assigning a given volume of it, *pro rata* with the number of population of the City of Chicago, would result in the lowering of the surface levels, and all adjoining waters down to the Gulf of St. Lawrence, and be prejudicial to both the manufacturing and commercial districts of all the intervening towns, as a consequence of which it would not be permitted, either by the Government of the United States or that of Canada. Hence the proposal is utterly impracticable of adoption, as its effects would soon become so insupportable to the people of both countries that they would arise in opposition, and Congress would be appealed to for relief, and damages be claimed.

6th.—As the sewage of populous towns and cities cannot be disposed of effectually, or with sanitary requirements, either by evaporation, precipitation, filtration, or its discharge into rivers above the line of commixture of tidal and fresh waters, or into lakes, or by mixture with great proportional volumes of water from our lakes, with immunity from the pollution of the potable waters thereof, there are but two methods left, viz., one for populous inland towns and cities, the sewage of which must be chemically discharged of its noxious exhalations and disposed of for fertilization, if practicable to do so; and the other by cremation, in which there is no danger of the pollution of water supplies, or insanitary effects. To operate it, involves the construction and maintenance of a furnace plant, and that the sewage, as received, must be as free from surface fluids as practicable, and that where sewers for the reception and conveyance of both sewage and surface water exist, as in large cities, independent drains be laid for the surface water.

7th.—That, great as this combined cost of reconstruction and construction would be, it is so inconsiderable, compared with the beneficial results to be attained by it, that the expenditure is not to be entertained as a bar to the method, for the result of the discharge of the water of our rivers above the line of commixture given will soon have to be faced squarely, as the destruction of the potability of the water of all rivers bordered by populous towns or cities will become eventually so extensive that it will interfere with the requirements of the people and of their horses and cattle. It will also cause the destruction of the fish, and how it is that the citizens of Chicago entertain the opinion that the operation of their drainage canal will be submitted to, and that the riparian residents of the rivers into which its sewage is discharged will submit to it passively, is wholly inexplicable to the writer.

Mr. Haswell.

8th.—That the discharge of sewage, crude or treated in any antiseptic manner, in a fresh-water river, is offensive, noxious and not to be entertained with any regard whatever to the sanitary requirements of its riparian residents; that it will not be submitted to; and any or all towns or cities contributing to the pollution of such water will not only not be permitted to continue in such practice, but will inexorably be required to dispose of their sewage in some other and proper manner.

9th.—That existing wells, for households, in densely populated towns and cities should be filled up and abandoned forthwith, and the vaults of all privies and tanning vats made water-tight, to arrest infiltration of any part of their contents to contiguous and subterranean watercourses, and to guard against the result of the ignorance and indifference of some people who disregard all sanitary requirements and permit the proximity of privies to their wells.

Finally, when this subject of the disposal of sewage is entertained in a proper manner, and such disposal is operated under sanitary requirements, the wonder will be how and why it was that any of the now existing methods, including the very restricted operation of cremation, for populous inland towns and cities, were tolerated.

Writer unknown.

WRITER UNKNOWN*.—The sole reason why cremation of garbage has been a success in England is that it is burned in ovens and not near boilers; that is to say, the cells in which it is destroyed are wholly of firebrick, and only when combustion is complete are the products brought into contact with the comparatively cold plates of a steam boiler. There is really no very serious difficulty in completely destroying refuse at a high temperature, as a simple calculation will show. Anyone who has a garden knows that ordinary garden rubbish, leaves, etc., will destroy itself if heaped up high above a small quantity of dry stuff. The initially dry stuff dries out the wet stuff which lies upon it, and this then burns and the whole heap is dried off and burned.

In England all refuse is collected together, *i. e.*, not separately, and includes ordinary house refuse, such as cinders and vegetable refuse. It is considered that this material contains 30% of water, 30% of combustible matter and 40% of inert matter, such as gravel, broken crockery and clinkers or ashes.

As carbon contains 14 647 B. T. U. per pound, 1 lb. of average refuse will contain 4 400 B. T. U. At 1 500° Fahr., the water will carry off less than 550 B. T. U., including latent heat and superheat. There will remain 3 950 B. T. U., to deal with. Allowing 18 lbs. of air per pound of fuel, there will be 54 lbs. of air, 0.3 lb. of fuel and 0.4 lb. of mineral matter to be heated up to a temperature of, say, 1 500°, or a

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* The manuscript of this discussion was received by the Secretary, from London, but no name was attached to it in any way. It is published here in the hope that the writer will furnish his name, so that it may be printed in *Transactions*.

Writer unknown. total of 6.1 lbs. to share in 3 850 B. T. U., or 631 units per pound. The mean specific heat of all furnace products and clinker, etc., is less than 0.25. Calling it 0.25, the resultant temperature would be 2 524° Fahr., or 631 × 4, which is sufficiently above 1 500° to allow for further excess of air. Moreover, as the air forms by far the larger weight of stuff passing through the furnace, it becomes a simple matter to add considerably to the temperature by heating the air in the flues beyond the destructor.

The reduction of temperature, due to the increase of specific heat of gases at high temperatures, need not be discussed. It will not pull down the temperature below 1 500 degrees.

The combustible elements in any refuse can be ascertained easily by having a bulk sample weighed and burned off in a gas retort, after being first dried, and again weighed, the second difference being combustible. If a refuse is so poor that it has not sufficient fuel in it to burn thoroughly, it ought to be mixed with the cheapest grade of coal obtainable and all burned together in a refractory cell. The placing of a boiler as one boundary of a destructor cell is the worst possible practice. Even good bituminous coal cannot be destroyed by such a device without smell and fumes.

The sloping grate, of course, is a great aid to the work, for the labor then consists only in helping forward the clinkered purified residue. The heat carried off by the water is partly recovered when the gases are passed finally through a boiler; but no sanitary engineer now attempts to use the heat from a destructor until destruction is complete and nothing but glowing gas remains. A simple calculation for any ordinary sample of refuse will show that it has power to heat up everything it contains to a clear red heat or higher.

Mr. Hering. RUDOLPH HERING, M. Am. Soc. C. E. (by letter.)—The discussion has revealed a fair unanimity of opinion regarding the fact that the garbage question has now reached a point when its proper solution requires the aid of the engineering profession, instead of being left for solution almost wholly to committees of city councils or of boards of health. It is also apparently agreed that different conditions demand different methods of disposal, and that each municipality should select the method which, after a careful study of the specific local conditions and a careful investigation of the cost of securing unobjectionable results, proves to be most economical.

It is further agreed that the problem must include a consideration of the methods and cost of handling all of the several kinds of refuse between the points of origin on the streets and the points of final disposal.

When opening the subject, its largeness precluded entering into details, but a number of these have been elaborated subsequently, and have added valuable information.

Mr. Hering. In reply to Mr. Baldwin the writer may state that there are at least three garbage furnaces in America, where, it is said, all the refuse is burned without the regular addition of coal, excepting to start the fires on Monday mornings, or whenever they have been interrupted. One is in Montreal, where the garbage is mixed with dry refuse and with domestic ashes, which, however, are screened at some seasons if not always. Another is at San Francisco, where there is a similar furnace and where the garbage is likewise mixed with dry rubbish and ashes. The third is at Atlanta, Ga., where the garbage and dry rubbish alone are burned, and no domestic ashes with the residuum of unburned coal, are added.

The writer was glad to hear from Mr. Parsons that his investigation had convinced him that the garbage and refuse in New York City, when mixed, would be self-combustible. Steam ashes, being the result of intelligent and economical firing, have no fuel value left, and always should be removed separately and utilized for filling, road-making, or as the body-material of mortar. But domestic ashes, containing 20% of unburned coal, have a fuel value beyond the cost of screening out the fine ashes, which value may be sufficiently great to utilize. Whether or not such utilization is economical, depends on the extra length of haul to the crematory, and on the cost of screening.

It would be very interesting and useful if the precise facts leading up to Mr. Parsons' conclusion could be made public. Generally, he intimates, the scientific treatment of garbage is fairly understood and could be put into practice, provided the means were available. But this understanding is not the only requisite for a solution of the present difficulties. It is also necessary that the public should appreciate it fully and have confidence in the recommendations, because the public must furnish the means to carry them out. To this end, an actual demonstration on a practical scale seems to be the *sine qua non*, showing that the treatment which engineers, after studying the special problem, believe to be the proper one, will be both successful and economical. Such a demonstration is yet lacking in our own country.

Most of the present disposal works were proposed by promoters, who succeeded in obtaining contracts to erect plants, and whose interest lies chiefly in immediate profit to themselves. An impartial and thorough investigation, in order to ascertain the best methods and results for ultimate instead of for immediate profit has not yet been undertaken by any city in this country. Dr. Soper states that the present moment is propitious for such an investigation to be made as regards New York conditions, where the existing methods are yet crude and quite expensive, even though 40% of the work of collecting and disposing of the garbage is done by private parties, over which the city has but little control.

The writer suggests that in his opinion a further profitable inves-

Mr. Hering. tigation would be a full and detailed report on the entire subject, containing itemized expenses, and setting forth clearly the methods of operation and the results obtained in those cities of Europe where this subject has been settled satisfactorily, and, for comparison, an equally detailed report on the existing conditions in several of our own cities. Such a comparative report, the writer believes, would be of great value in pointing out specifically and most forcibly the courses to be pursued in solving this problem at home. In fact, unless we either present the public with actual information of this kind or make an actual impartial demonstration in one of our large cities, it would seem that the proper solution of the garbage question in this country will be still further postponed.

Mr. Ball makes an appeal for the disposal of street sweepings by burning instead of by filling in land, and offers many statements to support it. Such a disposition is made in several cities of Europe. In view of the fact that this material forms a rich field for disease germs, its incineration is certainly to be preferred when practicable. There are, however, many cases, particularly in our country, where the quota of combustible matter is reduced so greatly by admixture with mineral matter from badly paved or unpaved streets, that burning becomes expensive. In such cases filling in land is not only cheaper, but may be without sanitary danger. Mr. Ball further discusses the demolition of infected buildings, and gives the precautions which should be taken in their demolition. This subject had not before been touched upon, and is of sufficient importance to have been made a part of the subject under discussion. The writer believes Mr. Ball's precautions to be wise and practicable.

Commissioner Woodbury, by his remarks, leaves a doubt resting on the financial preference of the incineration over the reduction process, yet produces no facts to substantiate it. Mr. Parsons, on the other hand, unhesitatingly states his belief that incineration of the garbage of New York City is cheaper than its reduction, but, likewise, without substantiation. These, and other statements, confirm the opinion expressed by the writer, that experiments on a large scale, combined with an exhaustive inquiry into the subject, are required to demonstrate the best as well as the most economical disposal.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XXIX. No. 4.
APRIL, 1903.

Edited by the Secretary, under the direction of the Committee on Publications.

Reprints from this publication, which is copyrighted, may be made on condition that the full title of Paper, name of Author, page reference, and date of presentation to the Society, are given.

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NEW YORK 1903.

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American Society of Civil Engineers.

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◆

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

House of the Society—220 West Fifty-seventh Street, New York.

Telephone Number, - - - 588 Columbus.
Cable Address, - - - "Ceas, New York."

Vol. XXIX. APRIL, 1903. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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April 1st, 1903.—The meeting was called to order at 8.40 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary, and present, also, 119 members and 25 guests.

The minutes of the meetings of March 4th and 18th, 1903, were approved as printed in *Proceedings* for March, 1903.

A paper entitled "The Filtration Works of the East Jersey Water Company, at Little Falls, New Jersey," by George W. Fuller, Assoc. M. Am. Soc. C. E., was presented by the author and illustrated with lantern slides. The paper was discussed by Messrs. Allen Hazen, J. P. A. Maignen, Rudolph Hering, C. L. Harrison, J. Waldo Smith, R. S. Weston, George C. Whipple, William B. Fuller, L. L. Tribus and the author.

A paper entitled "Automatic Modules for Regulating the Speed of Filtration," by Charles Anthony, Jr., M. Am. Soc. C. E., was presented by title. On this paper there was no discussion.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Baxter Lamont Brown, St. Louis, Mo.
Albert Harlow Dakin, Jr., New York City.
Charles Morton Emmons, Beaver Falls, Pa.
Fred Eugene Foss, State College, Pa.
Owen Bert French, Washington, D. C.
Morris Knowles, Pittsburg, Pa.
Carl Gustaf Emil Larsson, Pencoyd, Pa.
Samuel Phillips Mitchell, Philadelphia, Pa.
Henry Tegmeyer Porter, Greenville, Pa.
Charles Lewis Potter, Memphis, Tenn.
Henry Rohwer, St. Louis, Mo.
Henry Bedinger Rust, Pueblo, Colo.
Clifford Stanley Sims, New York City.
Leonard Chase Wason, Brookline, Mass.
Robert Patterson Woods, Indianapolis, Ind.

As Associate Members.

William Hoyt Balch, Washington, D. C.
Edward Joseph Carney, New York City.
Allan Wadsworth Carpenter, Jersey Shore, Pa.
Charles Corwin Crew, Versailles, Mo.
James Laird de Vou, Philadelphia, Pa.
Benjamin Franklin, Philadelphia, Pa.
Morgan Dodge Hayes, Pittsburg, Pa.
William Hale Kimball, Davenport, Iowa.
Francis Mason, New York City.
Sergius Pavlovitch Maximoff, St. Petersburg, Russia.
George Soter Miller, Fishers Island, N. Y.
James Adolphus Omberg, Jr., Memphis, Tenn.
Clifford Moses Pritchard, Leavenworth, Kans.
John Corneliou s Sesser, Kansas City, Mo.
Marshall Ney Shoemaker, Philadelphia, Pa.
James William Skelly, St. Louis, Mo.

The Secretary announced the election of the following candidates by the Board of Direction on March 31st, 1903:

As Juniors.

Mark Anthony Beltaire, Jr., New York City.
Edwin Merritt Holmes, Daiquiri, Cuba.
Augustus Kempkey, Jr., Oakland, Cal.
James Henry Miner, Fort Dodge, Iowa.

EGBERT JESSUP MOORE, Phœnixville, Pa.
GEORGE TILLEY SEABURY, New York City.
JAMES HAMPDEN SMALL, Jr., New York City.
HERBERT JOSEPH WILD, Portland, Me.

The Secretary announced the following deaths:

CHARLES ANDREWS KNOWLTON, elected Member October 2d, 1901; died March 2d, 1903.

ROBERT BLUM OLNEY, elected Junior January 3d, 1895; Associate Member September 5th, 1900; died March 19th, 1903.

WILLIAM JOHNSTON TAYLOR, elected Fellow May 10th, 1870; died March 25th, 1903.

Adjourned.

April 15th, 1903.—The meeting was called to order at 8.45 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary, and present also, 54 members and 8 visitors.

A paper entitled "An Investigation of the Properties of Brick Under Different Physical Conditions," by S. M. Turrill, Assoc. Am. Soc. C. E., was presented by the Secretary, who also read a communication on the subject from E. J. McCaustland, Assoc. M. Am. Soc. C. E.

The Secretary announced the death of WILLIAM WARREN CARD, elected Member September 5th, 1883; died April 4th, 1903.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

March 31st, 1903.—8.40 P. M.—President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Briggs, Craven, Croes, Davison, Knap, Kuichling, Pegram, Osgood, and Schneider.

The following resolution was passed:

"That in the future in any year the Collingwood Prize for Juniors is not awarded, a sum equal to the value of the Prize be appropriated for the purchase of books, photographs, or exhibits of American Engineering Works; such exhibits to be inscribed in a manner indicating their source; and that it be made the duty of the Library Committee to expend such funds."

The following gentlemen were added to the Local Committee of Arrangements for the Convention already announced:

J. C. GUILD, Chattanooga, Tenn.
GEORGE O. TENNEY, Spartanburg, S. C.
W. A. LELAND, Columbia, S. C.
NESBIT WINGFIELD, Augusta, Ga.
J. N. HAZLEHURST, Mobile, Ala.

The following resignations were accepted: Archibald Alexander Schenck, M. Am. Soc. C. E.; Walter Bruce Gormly, Jun. Am. Soc. C. E.

Applications were considered and other routine business transacted.

Eight candidates for admission as Junior were elected.*

Adjourned.

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* See page 128.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, May 6th, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and two papers will be presented for discussion, as follows: "A Small Rock-Fill Dam," by H. deB. Parsons, M. Am. Soc. C. E.; and "Deflection of Beams with Variable Moments of Inertia," by C. W. Hudson, M. Am. Soc. C. E. These papers were printed in *Proceedings* for March, 1903.

Wednesday, May 20th, 1903.—8.30 P. M.—At this meeting a paper, by D. M. Andrews, M. Am. Soc. C. E., entitled "The Economic Improvement of the Coosa and Alabama Rivers, in Georgia and Alabama," will be presented for discussion. This paper is printed in this number of *Proceedings.*

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many such searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction to the members who have made use of the resources of the Society in this manner has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared to the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches for members to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

ANNUAL CONVENTION OF 1903.

The Thirty-fifth Annual Convention will be held at Asheville, N. C., June 9th, 10th, 11th and 12th, 1903.

A circular will soon be issued giving information as to arrangements, which are in the hands of the following Committees:

Committee of the Board of Direction.

J. James R. Croes, *Chairman.*
George H. Pegram, Chas. Warren Hunt.

Local Committee.

J. L. Ludlow, *Chairman.*

William Cain,
Wilbur F. Foster,
George W. Frank,
J. C. Guild,
J. N. Hazlehurst,
W. B. W. Howe,
W. A. Leland,
J. Imbrie Miller,
William Moncure,
J. A. Montgomery,
E. T. D. Myers,
Arthur Pew,
George O. Tenney,
Nesbit Wingfield.

TOPICS FOR INFORMAL DISCUSSION.

Topic No. 1. Timber Tests. (See statement in detail as to this subject, on page 133.)

Topic No. 2. Sewage Purification. (This subject will be presented by Rudolph Hering, M. Am. Soc. C. E.)

Topic No. 3. In the treatment of the Mississippi River, is the Levee Theory justified by Experience?

Topic No. 4. Is it possible to make Concrete which will be Impervious to Water? If so, what is the best method?

Topic No. 5. What is the effect of Sea-Water upon Steel, and upon Steel and Concrete used in Combination, and is the use of Steel in Sea-Water admissible?

Topic No. 6. In view of the increasing weights of Rolling Stock, for what loadings should Railroad Bridges be designed?

Discussion on each of these subjects is invited. Communications from members who are unable to attend the Convention will be presented by the Secretary.

TIMBER TESTS.

This subject will be introduced for discussion at the Annual Convention by Gifford Pinchot, Assoc. Am. Soc. C. E., of the Bureau of Forestry, of the U. S. Department of Agriculture, who has prepared the following statement:

The Bureau of Forestry, of the United States Department of Agriculture, intends to resume the work of testing timber formerly carried on by the Division of Forestry during the years 1891–1896. A large portion of the groundwork covered by the proposed investigation is of interest to engineers, and it is the desire of the Bureau that the results obtained shall be of the greatest value to them. To this end it is hoped that those engineers interested in the application of timber to construction, will, in this discussion, offer suggestions and make criticisms which will aid the Bureau in planning this series of tests.

It is the intention of the Bureau to take up these tests in a thorough manner and devote whatever time may be necessary for the solution of the problems involved. It is expected that the plan of operation will be sufficiently complete, and the methods of tests so well chosen, that the data obtained may be accepted by all experts.

The following account of the proposed tests is of a very general nature. Those who are particularly interested can obtain a description of the proposed tests in greater detail on application to the Bureau of Forestry, Washington, D. C.

The Bureau aims at results of practical value, such as the values expressing the strength and stiffness of the principal merchantable species of timber of this country. Not only will this be done for timber now in use, but efforts will be directed to ascertaining the value for structural purposes of timbers at present not largely used, as, for example, the Western Hemlock and the Southern Gums. A thorough series of tests will be made of the timbers of the Pacific Slope, particularly the Red Fir, otherwise called Oregon Pine or Douglas Spruce, which is now finding its way in increasing quantities to eastern markets. If it should appear that the work done on the Southern Pines by the Division of Forestry during the years 1891–1896 has been sufficiently complete, the proposed tests will not cover these timbers.

Experimentation will be directed also in advance to the investigation of the effects of different factors of the testing processes on the results, such as speed of application of a load, method of moisture determination, the effect of moisture, and of volatile oils.

The investigation of the effect of technological operations, such as methods of kiln drying, methods of preserving timber, etc., will be undertaken.

In determining the values of the strength and stiffness of various merchantable timbers, tests will be made, both on timber collected from the market and on timber collected in the forest. Full-sized sticks, as used in construction, will in all cases be tested under their appropriate loadings.

Work is at present in progress at a station in California, on the different merchantable grades of these full-sized timbers, such as bridge stringers and car sills collected on the market. The locality of origin of the timbers is determined, and a full description of each stick, as well as a series of photographs of all six sides, is made a matter of record. Full information of the physical and mechanical properties of the sticks under test will be obtained.

The investigation of the effect of various conditions of forest growth on the physical and mechanical properties of timber will be undertaken whenever the Bureau is thoroughly prepared for this work.

It is hoped that the discussion will take up the need of making timber tests from the standpoint of the engineer. Suggestions are invited as to those particular matters which at present most need investigation. It is also desired that discussion shall take place concerning the methods of performing the tests, particularly as to the best method of determining the moisture in timber; and the best method of determining the shearing strength of timber.

It is hoped that a full criticism of the former tests, both as to methods and content, will be given.

It is recognized that timber is subject to a great number of variables. From the botanical standpoint, the ideal method of procedure would be to determine the properties of the wood fiber of each species representing the normal growth of straight-grained timber. With these standard values as a basis, inquiries could be directed to ascertain how much the values are affected by such variables as moisture, oil, speed of test, imperfection of structure due to direction of grain or knots, rate of growth, diseases of the tree, technological processes such as kiln drying or preserving, etc.; forest conditions, region, and growth. It would seem that the interests of all, whether engineers, manufacturers, or botanists, would be consulted by such a method of procedure. The particular series of tests on full-sized sticks of market timber would form part of this general scheme.

ACCESSIONS TO THE LIBRARY.

From March 11th to April 7th, 1903.

DONATIONS.*

STORAGE BATTERY ENGINEERING.

A Practical Treatise for Engineers. By Lamar Lyndon, Assoc. M. Am. Inst. E. E. Cloth, 9½ x 6¼ ins., 382 pp., illus. New York, McGraw Publishing Company, 1903. $3.00.

This book is intended to assist the practicing engineer in designing, installing and maintaining battery equipments, and to guide him in the selection of types of batteries and auxiliary apparatus best suited to the service which they are to perform, and at the same time impress upon the technical public, both the advantages and limitations of the storage battery in practice. Mathematics have been avoided as far as possible. The Osmotic and Thermodynamic theories of the storage battery have not been discussed, as their comprehension requires more electro-chemical knowledge than the majority of electrical engineers possess, and this work is intended to be a practical engineers' manual. The chapter headings are: General Theory of the Storage Battery; General Requirements; On Voltage and its Variation; On Quantity and Distribution of Active Material; On Electrolyte; On Quantity of Electrolyte; On Internal Discharge; On the Influence of Temperature; On Capacity Variation; On Internal Resistance; On Efficiency; On the Durability and Causes of Deterioration; On Diseases and their Remedies; On Care and Management; Types of Planté Plates; Methods of Planté Formation; Faure System; Applied Active Material Mixtures; Envelopes and Separators; Containing Cells; Assembling and Installing; Testing; Miscellaneous Data. There is an index of five pages.

SPECIFICATIONS FOR ELECTRIC RAILWAY BRIDGES. 1902.

By C. S. Davis. Paper, 9 x 6 ins., 8 + 48 pp. Toledo, C. S. Davis, 1902. 50 cents.

In these specifications an equivalent load has been used by the author for the reason that the wheel base and wheel loads for electric railway cars vary to such an extent that it seems a useless task to use a different wheel load and wheel base for every line. The equivalent load used is the same for any span length, and gives results reasonably close for any wheel base that is now being used. There are nine general divisions, as follows: General Description; Loads; Unit Stresses; Details of Design; Shop Work; Field Work; Quality of Material; Inspection; Maintenance.

HEATING AND VENTILATING BUILDINGS.

A Manual for Engineers and Architects. By Rolla C. Carpenter, M. Am. Soc. M. E. Fourth Edition, Revised and Enlarged. Cloth, 9 x 6 ins., 16 + 562 pp., illus. New York, John Wiley & Sons, 1903. $4.00.

The present edition of this work has been very largely re-written and considerable new matter added, the size of the book, as compared with the first edition, being increased by nearly one-third. Three new chapters have been added: One relating to the fan or blower for moving air, another to the general subject of mechanical systems of heating and ventilating, and a third to schoolhouse heating and ventilation. It is believed that the book in its present form describes the latest improvements in the art of heating and ventilating. It also gives directions for the construction and installation of all the various sytems of heating and ventilating now in use. The Contents are: Nature and Properties of Heat; Principles of Ventilation; Amount of Heat Required for Warming; Heat Given off from Radiating Surfaces; Pipe and Fittings Used in Steam and Hot-Water Heating; Radiators and Heating Surfaces; Steam-Heating Boilers and Hot-Water Heaters; Settings and Appliances; Methods of Operating; Various Systems of Piping; Design of Steam and Hot-Water Systems; Heating with Exhaust Steam; Non-Gravity Return Systems; Heating with Hot Air; Mechanical Ventilators; Mechanical Systems of Heating and Ventilating; Heating with Electricity; Temperature Regulators; Schoolhouse Warming and Ventilation; Specification Proposals and Business Suggestions; Appendix. There is an index of twenty pages.

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* Unless otherwise specified, books in this list have been donated by the Publishers.

DISINFECTION AND DISINFECTANTS.

A Practical Guide for Sanitarians, Health and Quarantine Officers. By M. J. Rosenau. Cloth, 8 x 6 ins., 353 pp., illus. Philadelphia, P. Blakiston's Son & Co., 1902. $2.00.

The preface states that this book has been written with the hope that it may help others who have to battle with the infection of the communicable diseases. The author has tried to set down the results of his experience gained in sanitary work of a public-health character, both in the field and in the laboratory. It has been his aim to state the important facts in a form to be of practical use to the disinfector. The subject has been considered from the standpoint of the disinfectant used, the object to be disinfected, and the disease for which the disinfection is done. In considering any subject from three points of view a certain amount of repetition is unavoidable. The chapter headings are: Introduction; Physical Agents; Gaseous Disinfectants; Chemical Solutions; Insecticides Applied to Disinfection Against the Insect-Borne Diseases; Disinfection of Houses, Ships and Objects; Disinfection for the Communicable Diseases. There is an index of seven pages.

THE ELECTRIC TELEPHONE.

By Edwin J. Houston and A. E. Kennelly. Second Edition, Enlarged. Cloth, 7 x 5 ins., 6 + 453 pp., illus. New York, Electrical World and Engineer, copyright 1902. $1.00. (Presented by the McGraw Publishing Co.)

The authors have prepared this little book on the telephone, in the hope of enabling those who are not trained in electro-technics to understand the main principles and method of operation of the telephone systems of to-day. Since the first edition much growth and development have taken place in telephonic engineering and practice. The authors have added three new chapters upon recent subjects of importance, and believe that by so doing, the book will be brought up to date. The chapter headings are: Introductory; Elementary Acoustic Principles; The Telephone Receiver; The Microphone Transmitter; The Induction Coil; Call Bells and Batteries; Single-Circuit Connections; Multiple-Circuit Connections; Isolated-Station Switchboards; Multiple Switchboards; Telephonic Circuits; Long-Distance Telephony; Radiphony and Miscellaneous Applications of Electricity; Common-Battery Systems; Visual Signals; Loaded Telephone Circuits. There is an index of twenty-seven pages.

THE ART OF ILLUMINATION.

By Louis Bell. Cloth, 9 x 6 ins., 339 pp., illus. New York, McGraw Publishing Co., 1902. $2.50.

The author states in the preface that this volume is a study of the utilization of artificial light. It is intended to deal, not with the problem of distributing illuminants, but with their application, and treats of the illuminants themselves only in so far as a knowledge of their peculiarities is necessary to their intelligent use. To compress the subject within reasonable bounds, it has been necessary to discuss general principles rather than concrete examples of artificial lighting. The Contents are: Light and the Eye; Principles of Color; Reflection and Diffusion; The Materials of Illumination—Illuminants of Combustion; The Materials of Illumination—Incandescent Burners; The Electric Incandescent Lamp; The Electric Arc Lamp; Shades and Reflectors; Domestic Illumination; Lighting Large Interiors; Street and Exterior Illumination; Decorative and Scenic Illumination; The Illumination of the Future; Standards of Light and Photometry. There is an index of five pages.

RAILROAD CONSTRUCTION, THEORY AND PRACTICE.

A Text-Book for the Use of Students in Colleges and Technical Schools. By Walter Loring Webb, Assoc. M. Am. Soc. C. E. Second Edition, Revised and Enlarged. Morocco, 7 x 4 ins., 17 + 675 pp., illus. New York, John Wiley & Sons, 1903. $5.00.

The preface states that the inconvenience of the octavo edition for field-work was found to be limiting the use of the book. It was therefore decided to recast the whole work and reduce the page from "octavo" to "pocket-book" size. Advantage was then taken of the opportunity to revise freely and to add new matter. The author's primary aim has been to produce a text-book for students, the subject-matter has therefore been cut down to that which may properly be required of students in the time usually allotted to railroad work in a civil-engineering curriculum. On this account no extended discussion has been given to the multitudinous forms of various railroad devices in the chapters on structures. The aim has been to teach the principles and to guide the students into proper methods of investigation. The Contents are: Railroad Surveys; Alignment; Earthwork; Trestles; Tunnels; Culverts and Minor Bridges; Ballast; Ties and Other Forms of Rail Support; Rails; Rail-Fastenings; Switches and Crossings; Miscellaneous Structures and Buildings; Yards and Terminals; Block Signaling; Rolling Stock; Train Resistance; Cost of Railroads; The Promotion of Railroad Projects; Operating Expenses; Distance; Curvature; Grade; Improvement of Old Lines; Adjustments of Instruments. There is an index of twenty-three pages.

BLACKWELL'S ISLAND BRIDGE IN THE CITY OF NEW YORK.

By Gustav Lindenthal. Paper, 24 x 15 ins., 6 plates. New York, 1903. 60 cents. (Donated by the author.)

SELF-PROPELLED VEHICLES.

A Practical Treatise on the Theory, Construction, Operation, Care and Management of All Forms of Automobiles. By James E. Homans. Cloth, 9 x 6 ins., 6 + 626 pp., illus. New York, Theo. Audel & Company, 1902. $2.00.

The preface states that the treatment of subjects throughout this work has been kept as nearly as possible in the lines popularly called "non-technical," and the various theories and problems involved in the construction and operation of the prevailing types of motor road carriages have been stated as clearly and simply as possible, in order that the involved situations may be readily comprehended by all readers. The fundamental principles of the several types of motor, particularly of the gasoline engine, have been treated at considerable length, in order that the facts may be comprehended in their new relations. It has been the author's aim to state and discuss the most important points of this already immense subject, and to treat only of constructions that have been proven thoroughly practical. There is an index of six pages.

A PHILOSOPHICAL ESSAY ON PROBABILITIES.

By Pierre Simon, Marquis de Laplace. Translated from the Sixth French Edition by Frederick Wilson Truscott and Frederick Lincoln Emory, M. Am. Soc. M. E. Cloth, 8 x 5 ins., 4 + 196 pp. New York, John Wiley & Sons, 1902. $2.00.

This essay is the development of a lecture on probabilities which the author delivered in 1795 to the normal schools whither he had been called, by a decree of the national convention, as professor of mathematics, with Lagrange. The author presents here, without the aid of analysis, the principles and general results of the theory of probabilities, applying them to the most important questions of life.

Gifts have also been received from the following:

Am. Inst. of Min. Engrs. 17 pam.
Assoc. Parisienne des Propriétaires d'Appareils à Vapeur. 1 vol.
Binghamton, N. Y.—City Engr. 1 pam.
Bond, Edward A. 2 pam.
Boston, Mass.—City Auditor. 5 bound vol.
Boston, Mass.—Fire Dept. 8 bound vol., 10 pam.
Boston, Mass.—Street Dept. 7 bound vol.
Bouscaren, G. 1 bound vol.
Brandon, Vt.—Town Officers. 7 pam.
Brooklyn, N. Y.—Commr. of Pub. Works. 2 pam.
Buck, Henry R. 1 bound vol., 18 pam.
Burlington, Vt.—City Clerk. 22 vol.
Burlington, Vt.—Water Dept. 1 pam.
Cairns, Robert A. 1 pam.
Cambridge, Mass.—City Clerk. 6 bound vol., 1 vol.
Canada—Chf. Engr. of Rys. and Canals. 1 vol., 3 pam.
Canada—Tidal Survey. 4 pam.
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Die Gleichstrommaschine, Theorie, Konstruktion, Berechnung, Untersuchung und Arbeitsweise derselben. Von E. Arnold. Vol. I. Berlin, Julius Springer, 1902.

Hydraulic Power and Hydraulic Machinery. By Henry Robinson, M. Inst. C. E., M. I. M. E. Second Edition, Revised and Enlarged. London, Charles Griffin and Company, Limited, 1893.

The Balancing of Engines. By W. E. Dalby, M. Inst. C. E., M. I. M. E. New York, Longmans, Green and Co.; London, Edward Arnold, 1902.

The Steam Turbine. By Robert M. Neilson, Assoc. M. I. M. E. Longmans, Green and Co., London, New York and Bombay, 1902.

The Thermodynamics of Heat-Engines. By Sidney A. Reeve. New York, The Macmillan Company; London, Macmillan & Co., Ltd., 1903.

Die Geschichte des Eisens in technischer und kulturgeschichtlicher Beziehung. Von Dr. Ludwig Beck. Vol. V, Pt. 8. Braunschweig, Friedrich Vieweg, 1903.

Rand, McNally & Co.'s Indexed Atlas of the World. Historical—Descriptive—Statistical. 2 vol. Rand, McNally & Company, Chicago, New York, London, Berlin, copyright 1902.

The New Volumes of the Encyclopædia Britannica, constituting, in combination with the existing Volumes of the Ninth Edition, the Tenth Edition of that Work, and also Supplying a New, Distinctive, and Independent Library of Reference Dealing with Recent Events and Developments. Vols. I to VII, Forming Vols. XXV to XXXI of the Complete Work. Adam and Charles Black, London and Edinburgh, The Encyclopædia Britannica Company, New York, 1902.

Controle des Chemin de Fer et des Tramways. Par Jean de la Ruelle. Paris, Vve. Ch. Dunod, 1903.

The Trans-Siberian Route; or, Notes of a Journey from Peking to New York in 1902. By Clarence Cary. New York, The Evening Post Job Printing House, 1902.

Tracé et Terrassements. Tracé par P. Frick; Terrassements par J. L. Canaud. Paris, Vve. Ch. Dunod, 1903.

Calcareous Cements: Their Nature and Uses, with some Observations upon Cement Testing. By Gilbert R. Redgrave, Assoc. Inst. C. E. London, Charles Griffin and Company, Limited, 1895.

Slow Burning or Mill Construction. Report No. V of the Insurance Engineering Experiment Station. Boston, 1902.

SUMMARY OF ACCESSIONS.

From March 11th to April 7th, 1903.

Donations (including 355 duplicates)	886
By purchase	20
Total	906

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JUNIORS.

GORMLY, WALTER BRUCE	March 1st, 1903

DEATHS.

KNOWLTON, CHARLES ANDREWS	Elected Member, October 2d, 1901; died March 2d, 1903.
OLNEY, ROBERT BLUM	Elected Junior, January 3d, 1895; Associate Member, September 5th, 1900; died March 4th, 1903.
TAYLOR, WILLIAM JOHNSTON	Elected Fellow, May 10th, 1870; died Feb. 17th, 1903.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST.

(March 11th to April 7th, 1903.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

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In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
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(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
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(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des École Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
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(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Engrs., New York City, 50c.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
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(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
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(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.

LIST OF ARTICLES.

Bridge.

Electric Railway Bridges. Wilbur J. Watson. (1) Jan.

A Comparison Between Eye-Bar Chains and Wire Cables for Suspension Bridges. Wilhelm Hildenbrand, M. Am. Soc. C. E. (13) Mar. 12.

Report of Special Commission of Engineers on the Plans for the Manhattan Bridge, New York City. (13) Mar 12; (14) Mar. 21.

A Railway Trestle with Bents of Reinforced Concrete.* Wm. A. Allen, Assoc. M. Am. Soc. C. E. (13) Mar. 12.

The Erection of the Miramichi Bridge.* (14) Mar. 14.

Arch Bridge Construction on the C., M. & St. P. Ry.* (18) Mar. 14.

Completion of the Floor of the New East River Bridge.* (46) Mar. 14.

A Novel Plan for Removing a Bridge.* (40) Mar. 20.

The Chicago Great Western and the Fort Dodge Bridge.* (40) Mar. 20.

The Delaware River Bridge of the Pennsylvania Railroad at Trenton, N. J.* (40) Mar. 20.

A Conventional System of Treating Wheel Loads. M. F. Brown, Assoc. M. Am. Soc. C. E. (13) Mar. 26.

Stone Arch Bridge on the Chicago, Milwaukee & St. Paul Ry. at Watertown, Wis.* (13) Mar. 26.

The Manhattan Valley Viaduct of the New York Rapid Transit Railroad.* (14) Mar. 28.

Le Viaduc de Kinzua (Etats-Unis).* A. Morizot. (35) Mar.

Electrical.

Electric Shop Drive: Discussion.* W. A. Layman, W. Cooper, Ferdinand Schwedtmann. (1) Jan.

Some Interesting Experiences Connected with the Manipulation and Installation of Cables. H. W. Fisher. (58) Jan.

The Evolution of the Telephone Switchboard. Thomas D. Lockwood. (42) Feb.

An Automatic Telephone Operator. William J. Hammer. (42) Feb.

Electrically Driven Shops. (65) Feb.

The Largest Power Plant in New Hampshire (Amoskeag Mfg. Co.).* (27) Feb. 28.

Some Engineering Features of the Bedell System of Composite Transmission.* A. S. McAllister. (27) Feb. 28.

Radiant Efficiency of the Mercury Arc. (27) Feb. 28.

Analysis of the Seventh Annual Report of the Public Lighting Commission, Detroit, Mich. (27) Feb. 28.

A Study of the Phenomenon of Resonance in Electric Circuits by the Aid of Oscillograms. M. B. Field. (Abstract of paper read before the Glasgow Section, Inst. Elec. Engrs.) (26) Serial beginning Mar. 6.

The Joint Transmission of Differing Currents. Frederick Bedell. (Abstract of paper read before the Elec. Soc. of Cornell Univ.) (26) Mar. 6.

The Electric Lighting of Eastbourne.* (26) Mar. 13.

Some Notes on Continental Power House Equipment. H. L. Riseley, A. M. I. E. E. (Abstract of paper read before the Newcastle Local Section, Inst. Elec. Engrs.) (26) Mar. 13.

The 22000-Volt Transmission Installation of the Northern California Power Company.* (27) Mar. 14.

Electricity as a Motive Power in Mechanical Flight.* T. Byard Collins. (27) Mar. 14.

The Heyland Induction Motor. Boy de la Tour. (27) Serial beginning Mar. 14.

High Temperature Electro-Chemistry: Notes on Experimental and Technical Electric Furnaces.* R. S. Hutton, A. I. E. E., and J. E. Petavel, A. M. I. E. E. (Paper read before the Inst. of Elec. Engrs.) (19) Serial beginning Mar. 14.

Kircaldy Electricity Works.* (26) Mar. 20.

Test of the National Telegraphone.* (18) Mar. 21.

Bull's Selective System of Wireless Telegraphy.* A. Frederick Collins. (46) Mar. 21.

The Testing of Recording Wattmeters on the Consumer's Premises by Means of a Specially Constructed Portable Test Meter. W. J. Mowbray. (27) Mar. 21.

A Notable Invention in Rapid Telegraphy. Romyn Hitchcock. (27) Mar. 21.

Formal Opening of the Frontier Independent Telephone Exchange, Buffalo, N. Y.* Frank C. Perkins. (27) Mar. 21.

Electric Ignition in Gas Engines. Sir David Salomons, Bart. (26) Serial beginning Mar. 27.

The Principles of a New Method of Electric Lighting. Paul Hoho. (27) Mar. 28.

The Induction Coil. James Edmund Ives. (27) Mar. 28.

The Development and Use of the Small Electric Motor.* Fred. M. Kimball. (9) Apr.

Alternating Current for Light and Power. Chas. F. Scott, Pres. Am. Inst. E. E. (10) Apr.

Electrical Developments in Russia.* Thomas E. Heenan. (10) Apr.

Power Test of an Electrically-Driven Shaper.* (25) Apr.

Motor-Driven Machine Tools.* (25) Apr.

The Application of Individual Motor Drives to Old Machine Tools; McKees Rocks Shops, Pittsburg & Lake Erie R. R.* R. V. Wright. (25) Serial beginning Apr.

Fonctionnement de l'Éclairage Électrique sur les Réseaux de Traction. Maurice Soubrier. (36) Serial beginning Feb. 25.

Usine Hydro-Électrique des Côtes de Sassenage (Isère).* Maduit. (33) Mar. 7.

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* Illustrated.

Marine.

Changes in the Armament of Warships. (12) Mar. 13.
Multitubular Marine Boilers and Their Features.* William H. Fowler. (47) Mar. 14.
Some Miscellaneous Types of Marine Boilers.* William H. Fowler. (47) Serial beginning Mar. 28.
A New Sighting Gear for Naval Guns and Gunnery Signaling Apparatus.* (46) Mar. 28.

Mechanical.

Abatement of the Smoke Nuisance.* Report by Committee, Engineers' Society of Western New York. (1) Jan.
Notes on the Design of Riveter Yokes.* Chester B. Albree. (58) Jan.
The Theory of Operation of the Gasoline Engine.* E. C. Oliver. (1) Feb.
Electrically Driven Shops. (65) Feb.
The Largest Power Plant in New Hampshire (Amoskeag Mfg. Co.).* (27) Feb. 28.
Economy in the Use of Coal for the Production of Power. Ira N. Hollis. (28) Mar.
Waste Heat Engines. Edward F. Miller. (28) Mar.
Cranes for Railroad Shops.* G. R. Brandon. (39) Mar.
Standard Specifications for Cast-Iron Pipe and Special Castings.* New England Water-Works Assoc. (28) Mar.
Inauguration of the New Gas-Works at Granton (Edinburgh).* (66) Mar. 3.
The Coke Plant at the Smethwick Gas-Works; a Gravity Bucket Conveyor for Feeding Water-Gas Plant.* (66) Mar. 3.
The Fischer Air-Gas System.* (66) Mar. 3.
Calorimetry of Gaseous and Liquid Fuels. W. Garnet Wernham. (Extracts from Paper read before the Junior Inst. of Engrs.) (66) Mar. 3.
The Crystal Palace Motor-Car Show.* (11) Mar. 6.
Indicating High-Speed Steam Engines.* A. Marshall Arter, A. M. I. C. E. (12) Mar. 6.
Gas Engines with Recent Improvements.* James Atkinson. (Paper read before the Manchester Assoc. of Engrs.) (47) Mar. 7.
Combined Oil-Carburetted and Blue Water-Gas Plant at Smethwick.* (66) Mar. 10.
Tar Fog.* William Everitt. (Paper read before the Manchester District Inst. of Gas Engrs.) (66) Mar. 10.
The Donora Plant (Union Steel Co.). (20) Mar. 12.
Large Stop Valves for High Pressure Steam. J. Hamilton Gibson. (62) Mar. 12.
The Petavel-Kingsmill Recording Pressure Gauge.* (11) Mar. 13.
A New Steam Motor Car.* (12) Mar. 13.
The Works of the Wellman-Seaver-Morgan Engineering Company.* (22) Mar. 13.
Central Station Gas Engines.* C. H. Williams. (Paper read before the Wisconsin Gas Assoc.) (24) Mar. 16.
Hydraulic Experiments on a Plunger Pump.* John Goodman. (Paper read before the Inst. of Mech. Engrs.) (62) Serial beginning Mar. 19.
A Modern Coke Oven.* (22) Mar. 20.
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The Cold Storage Plant in the Cornell Medical College.* (14) Mar. 21.
A Visit to M. de Brouwer at Bruges; a New Charging Machine of Original Design.* (66) Mar. 24.
A Combination Dellwik Water-Gas and Peebles Oil-Gas Plant at Cleethorpes.* (66) Mar. 24.
A Method of Calculating the Range of Speed to be Obtained from a Pair of Equal Cones. Frank B. Kleinhaus. (13) Mar. 26.
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PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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PAPERS AND DISCUSSIONS.

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THE ECONOMIC IMPROVEMENT OF THE COOSA AND ALABAMA RIVERS, IN GEORGIA AND ALABAMA.

By D. M. Andrews, M. Am. Soc. C. E.

To be Presented May 20th, 1903.

The Coosa River is formed by the junction of the Oostanaula and Etowah Rivers at Rome, Ga., which streams have their sources in the mountains of Northern Georgia.

The Oostanaula and its tributary, the Coosawattee, are navigable the year round for light-draft boats from Rome, Ga., to Carter's Landing, a distance of 105 miles.

The Coosa has always been navigable from Rome, Ga., to Greensport, Ala., a distance of 162 miles. From Greensport to Lock No. 4, Ala., a distance of 26 miles, the river has been made navigable for boats of 4-ft. draft by the construction of three locks and four dams, and by channel excavation at points between the dams. From Lock No. 4 to Wetumpka, Ala., a distance of 116 miles, there occurs a succession of rapids having a combined fall of 123 ft. In this section no work of improvement has been done, except at Wetumpka, where the

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Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

masonry of Lock No. 31 has been finished and a lock-master's house built. From Wetumpka to the mouth of the Coosa, a distance of 14 miles, the fall is gentle, and no locks and dams will be required. From Wetumpka to Mobile, Ala., a distance of 377 miles, there has always existed navigation for light-draft boats the year round.

It will thus be seen that on this system of rivers there would be, with the improvement of the 116 miles now closed to navigation, a water route of transportation from the mountains of Georgia to the Gulf, at Mobile, a distance of 786 miles.

The Coosa and Alabama Rivers were discovered by DeSoto in 1540. He marched down the entire length of the Coosa, and down the Alabama to the Choctaw Bluff, where, in an engagement with the tribe of Mobile Indians, his force was greatly weakened, though he almost annihilated the tribe of Indians.

After DeSoto's glimpse of them, these rivers almost disappeared from the knowledge of civilized man for nearly a century and a half. The words of Mark Twain, referring to the discovery of the Mississippi by the same explorer, apply equally well to the Coosa and Alabama Rivers:

> "Apparently nobody happened to want such a river; nobody needed it, nobody was curious about it; so, for a century and a half, the Mississippi remained out of the market and undisturbed. When DeSoto found it, he was not hunting for a river, and had no present occasion for one, consequently, he did not value it or even take any particular notice of it."

Geologically, the Coosa flows through the formations of the Paleozoic Era to within 27 miles of Wetumpka. Through this last part of its course it flows over crystalline rocks of pre-Cambrian origin, and at Wetumpka enters the coastal plain and the Cretaceous formation.

Through its upper course the river passes through the Coosa coal field near Lock No. 4, and, in places, the bluffs forming its banks contain great deposits of iron ore and limestone. In this section occur also deposits of bauxite, roofing slates, and great forests of long-leaf (Southern) pine and hard woods of many varieties.

The drainage area of the Coosa Basin, to Riverside, Ala., 113 miles above Wetumpka, including its tributaries, is given by the Hydrographic Division of the United States Geological Survey at 6 850 sq. miles.

The country adjacent to the Alabama River, while rich, agriculturally, has few, if any, mineral resources.

The banks of the Coosa, over the 116 miles to be improved, are generally high, and in many places they are precipitous, rocky bluffs. On such a stream, then, high lifts for locks and dams could be used without submerging much of the adjoining lands.

The questions now arise: First, what is the economic depth? and, second, what is the economic lift? Upon the correct answers to these two questions depends the proper solution of the problem, and in answering them the effort will be made to reduce the problem to the economic basis of business principles; the principles that govern the location of railroads, and the inauguration and construction of other works of a public character.

Two depths for the navigation of these rivers have been proposed namely, 4 ft. and 6 ft. The present discussion, therefore, will be confined to these two depths, for to extend it to others would carry the paper far beyond the limits proposed.

Acting under the direction of Captain R. R. Raymond, Corps of Engineers, U. S. A., the writer has deduced two equations, showing the relations between lift and cost of locks and accessories of standard design for the Coosa River, one for 4-ft. and one for 6 ft. navigation. The equations, the method of their deduction, and the theoretic economic effect of the use of the economic lifts are given in what follows, together with a discussion of other economic questions relating to the improvement.

Assuming the river to have a uniform slope and cross-section, the cost of one lock can be stated as follows:

$Y =$ cost of one lock and accessories, in terms of the lift, $= C +$ cost of excavation + cost of lock-walls + cost of wing-walls + cost of gates + cost of valves + cost of dam + cost of abutment + cost of guide piers + cost of engineering, inspection and office expenses.

The constant, C, includes:

Gate-maneuvering machinery	$410
Coffer-dam	5 000
Lock house	3 000
Fencing and outbuildings	1 500
Lock site	1 000
Miter-sills	1 206
	$12 116

The expression for the variable costs entering the equation, in which x, the lift, is a factor, are as follows:

Cost of excavation =

$$\left(\frac{x + m + d + e + w}{10}\right) l\, e$$

Cost of walls =

$$\tfrac{1}{27}\left[\left(k + \frac{m + x + d + e}{2}\right)\left(\frac{m + x + d + e}{2}\right) 2\, l + \left(\frac{m + x + d + e}{2} - k\right)(m + x + d + e)\, l''\right]$$

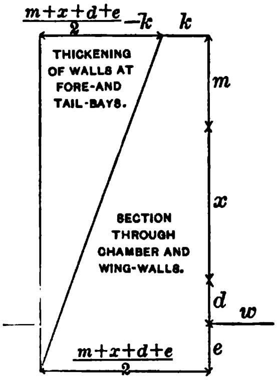

$\frac{m+x+d+e}{2}-k$
k
THICKENING OF WALLS AT FORE-AND TAIL-BAYS.
m
x
SECTION THROUGH CHAMBER AND WING-WALLS.
d
w
e
$\frac{m+x+d+e}{2}$

Fig. 1.

Cost of wing-walls =

$$\tfrac{1}{27}\left(k + \frac{m + x + d + e}{2}\right)\left(\frac{m + x + d + e}{2}\right) l'''$$

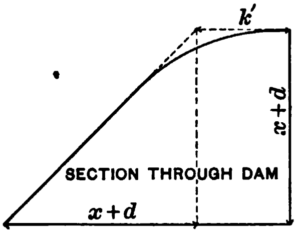
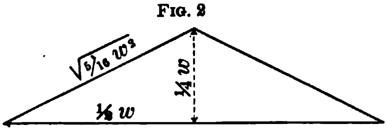


Fig. 2

Cost of gates =

$$4\, s\,(m + x + d)\sqrt{\tfrac{5}{16}\, w^2}$$

Cost of valves $= s'\left(\dfrac{4\, A\sqrt{x}}{+ c\sqrt{2\, g}}\right)$



PLAN OF GATES
Fig. 3.

Cost of dam =

$$\tfrac{1}{9}\, l'\left[(2\, k' + x + d)\left(\frac{x + d}{2}\right)\right]$$

Cost of abutment $= \tfrac{8}{27}\Big[p\,(2\, x + 2\, d + 2\, k' + n)\left(\dfrac{x + d + n}{2}\right) + \tfrac{1}{3}\left(\dfrac{x + d + n}{2}\right)^2 \left(2\, x + 2\, d + n\right) + \left(\dfrac{x + d + n}{2} + v\right)(x + d + n)\, k'\Big]$

Cost of guide piers = 300 x.

Cost of engineering, inspection, etc., = 1 500 x.

The values given the letters are the respective dimensions, etc., proposed for the locks, dams, etc., except the length of the dams, which is assumed. Unit prices are based upon the cost of similar work on this and the Warrior River.

l = length of lock, over all = 400 ft.;
m = guard of lock-walls = 8 ft.;
w = width of lock-chamber = 52 ft.;
k = width of lock and wing-wall coping = 4 ft.;
d = depth of water over miter-sills = 4 and 6 ft.;
s = cost per square foot of gate = \$3.81;
s' = cost per square foot of valve = \$15.59;
A = area of lock-chamber = 16 744 sq. ft.;
t = 360 seconds of time;
c = 0.635, determined from experiments at Lock No. 3, Coosa River;
k' = width of crest of dams = 8 ft.;
l' = average length of dams = 800 ft.;
p = width of abutment coping = 4 ft.;
n = guard of abutment = 14 ft.;
v = length of abutment stem = 10 ft.;
l'' = half length of heavy walls at fore- and tail-bays = 140 ft.;
l''' = length of wing-walls = 100 ft.;
e = depth of excavation = 4 ft.;
g = acceleration due to gravity = 32.2;

Substituting these values in the foregoing equations, and making $d = 4$, we get for 4-ft. navigation:

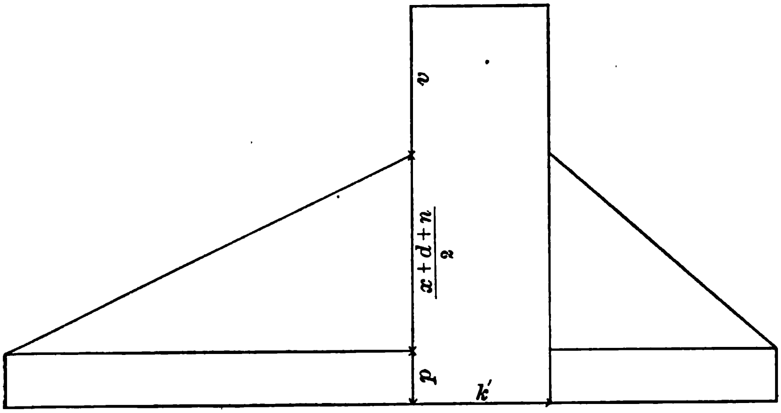
$C = \$12\,116.00$;
Cost of excavation = $\$10\,880 + 160x$;
Cost of lock-walls = $\$22\,234.07 + 2\,509.62x + 70x^2$;
Cost of wing-walls = $\$2\,488.88 + 259.26x + 6.48x^2$;
Cost of gates = $\$5\,316.32 + 443.03x$;
Cost of valves = $\$569.19\sqrt{x}$;
Cost of dam = $\$3\,555.55 + 1\,066.67x + 44.44x^2$;
Cost of guide piers = $\$300x$;
Cost of engineering, inspection, etc., = $\$1\,500x$;
Cost of abutment = $\$1\,403.85 + 145.78x + 4.69x^2 + 0.0494x^3$.

And $Y = \$57\,994.67 + 569.19\sqrt{x} + 6\,384.36x + 125.61x^2 + 0.0494x^3 \ldots\ldots (1)$

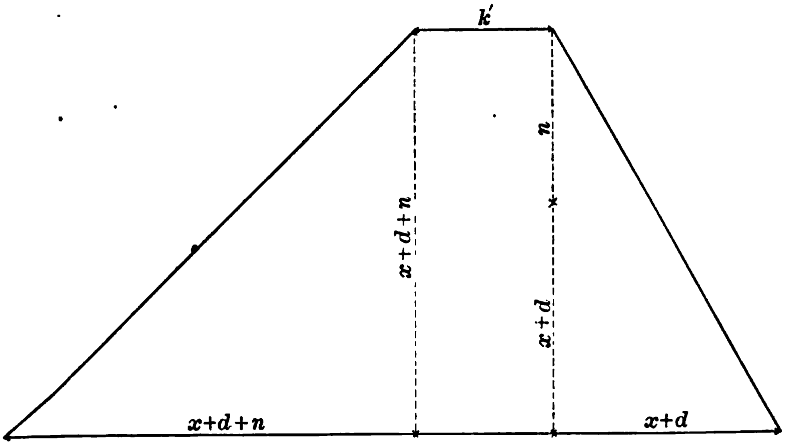
Again, substituting in the equations the values of the letters, and making $d = 6$, we get, for 6-ft. navigation:

$C = \$12\,116.00$:
Cost of excavation = $\$11\,200 + 160x$;
Cost of lock-walls = $\$27\,533.33 + 2\,789.63x + 70x^2$;

SKETCH OF ABUTMENT.



PLAN.



FRONT ELEVATION.

Fig. 4.

Cost of wing-walls = $\$3\ 033.33 + 285.19x + 6.48x^2$;

Cost of gates = $\$6\ 202.38 + 443.03x$;

Cost of valves = $\$569.19\sqrt{x}$;

Cost of dam = $\$5\ 866.67 + 1\ 244.44x + 44.44x^2$;

Cost of guide piers = $\$300x$;

Cost of engineering, inspection, etc., = $\$1\ 500x$;

Cost of abutment = $\$1\ 702.72 + 165.13x + 4.99x^2 + 0.9494x^3$,

And $$Y = \$67\ 654.43 + 569.19\sqrt{x} + 6\ 887.42x + 125.91x^2 + 0.0494x^3 \quad \text{.. .... (2)}$$

The fall from the upper pool at Lock No. 31 to the lower pool at Lock No. 4 is 309 ft. Let the number of locks required, with any lift, x, to overcome this fall = N; then $N = \frac{309}{x}$, and the cost of the improvement, exclusive of levees and overflowed lands, the cost of which is at present unknown, is $Y \times N$.

Tables Nos. 1 and 2 give the values of Y and N, and the total cost of the improvement, for every value of x, increasing by increments of 1 ft. from 5 to 30 ft., inclusive, for both 4-ft. and 6-ft. navigation. The curves in Fig. 5 show graphically the costs given in the tables.

TABLE No. 1.—VALUES OF Y AND N, AND TOTAL COST OF THE IMPROVEMENT FOR EVERY VALUE OF x, INCREASING BY INCREMENTS OF 1 FOOT FROM 5 TO 30 FEET.

FOR 4-FOOT NAVIGATION.

x, in feet.	Y.	N.	$Y \times N$. Costs of system.	
5..............	$94 334.38	61.8	$5 829 865	
6..............	102 227.70	51.5	5 264 727	
7..............	110 362.94	44.1	4 867 006	
8..............	118 743.81	38.6	4 583 512	
9..............	127 371.89	34.3	4 368 786	
10..............	136 247.31	30.9	4 210 042	
11..............	145 375.02	28.1	4 085 038	
12..............	154 751.92	25.75	3 984 862	
13..............	164 380.24	23.77	3 907 318	
14..............	174 260.53	22.07	3 845 930	
15..............	184 393.53	20.6	3 798 507	
16..............	194 779.70	19.31	3 761 196	
17..............	205 419.54	18.17	3 732 473	
18..............	216 313.78	17.17	3 714 108	
19..............	227 462.59	16.27	3 700 816	
20..............	238 866.56	15.45	3 690 488	
21..............	250 526.10	14.7143	3 686 316	21.5 ft. economical lift.
22..............	262 441.59	14.05	3 687 304	$3 685 751. $N = 14.3721$.
23..............	274 613.44	13.435	3 689 432	
24..............	287 042.01	12.87	3 694 233	
25..............	299 727.74	12.36	3 704 635	
26..............	312 670.92	11.88	3 714 531	
27..............	325 872.05	11.44	3 727 976	
28..............	339 331.34	11.04	3 746 218	
29..............	353 049.16	10.65	3 759 974	
30..............	367 025.89	10.30	3 780 367	

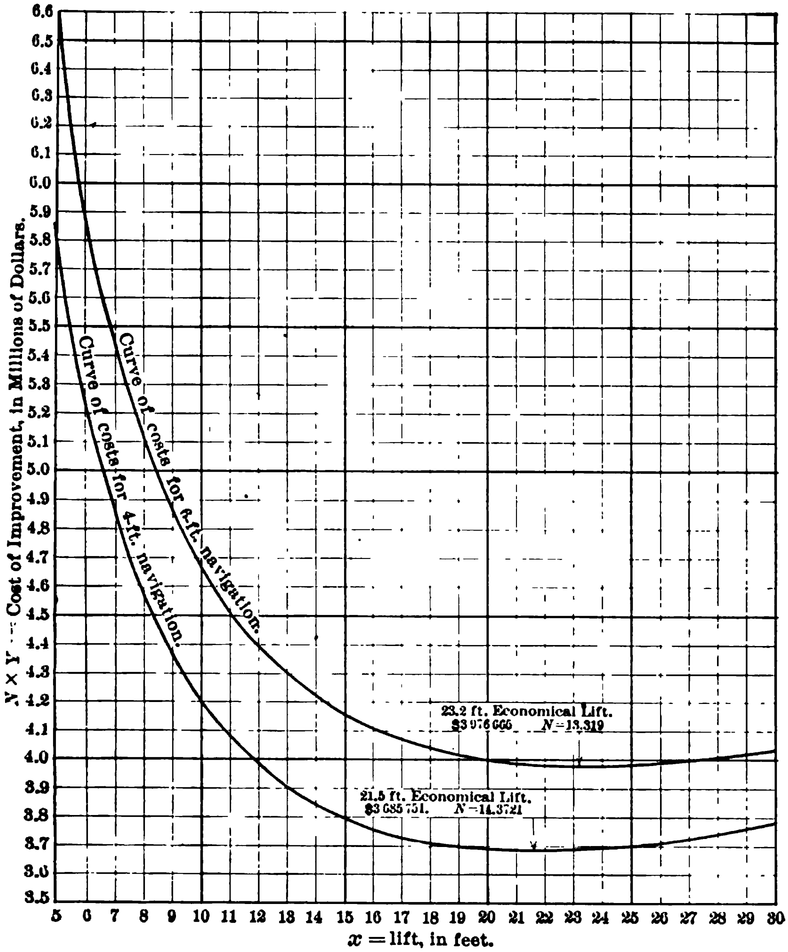

6.6
6.5
6.4
6.3
6.2
6.1
6.0
5.9
5.8
5.7
5.6
5.5
5.4
5.3
5.2
5.1
5.0
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4.0
3.9
3.8
3.7
3.6
3.5
N × Y = Cost of Improvement, in Millions of Dollars.
Curve of costs for 6-ft. navigation.
Curve of costs for 4-ft. navigation.
23.2 ft. Economical Lift.
$3 976 666 N = 13.319
21.5 ft. Economical Lift.
$3 685 751. N = 14.3721
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
x = lift, in feet.

FIG. 5.

TABLE No. 2.—VALUES OF Y AND N, AND TOTAL COST OF THE IMPROVEMENT FOR EVERY VALUE OF x, INCREASING BY INCREMENTS OF 1 FOOT FROM 5 TO 30 FEET.

FOR 6-FOOT NAVIGATION.

x, in feet.	Y.	N.	$Y \times N$. Costs of system.	
5	$106 518.21	61.8	$6 582 825	
6	114 916.61	51.5	5 918 205	
7	123 558.84	44.1	5 448 945	
8	132 447.24	38.6	5 112 463	
9	141 583.51	34.3	4 856 314	
10	150 972.11	30.9	4 665 048	
11	160 604.71	28.1	4 512 992	
12	170 491.55	25.75	4 390 157	
13	180 690.51	23.77	4 293 587	
14	191 021.95	22.07	4 215 853	
15	201 666.68	20.6	4 154 334	
16	212 565.26	19.31	4 104 635	
17	223 718.11	18.17	4 064 958	
18	235 125.82	17.17	4 037 110	
19	246 788.80	16.27	4 015 254	
20	258 707.53	15.45	3 997 031	
21	270 882.41	14.71	3 984 680	
22	283 313.87	14.05	3 980 560	
23	296 002.25	13.4348	3 976 731	23.2 ft., economical lift.
24	308 947.99	12.875	3 977 705	$3 976 665, $N = 13.319$.
25	322 151.53	12.36	3 981 793	
26	335 618.05	11.88	3 987 083	
27	349 333.21	11.44	3 996 372	
28	363 811.90	11.04	4 010 963	
29	377 549.94	10.65	4 020 907	
30	392 047.44	10.30	4 038 089	

The present project for the improvement of the Coosa River contemplates the building of twenty-seven locks and dams, from Lock No. 5 to Lock No. 31, inclusive. Lock and lock-house No. 31 have been completed, but the dam, gates, valves, etc., are yet to be built.

Table No. 3 gives the estimated cost of the improvement under the present project; the cost by Equations 1 and 2 for the lifts proposed in the present project, and the minimum costs by Equations 1 and 2, using the economical lifts. It will be noticed that the locks and dams provided for in the approved project, from Nos. 5 to 30 inclusive, have a combined lift of 296 ft., leaving 13 ft. fall in parts of the river where the slope is gentle. It is in these parts that $407 201 would be expended for channel work. In the estimates by Equations 1 and 2 it is proposed to back the water from one lock to another, and locate all locks so that channel work would be eliminated. The difference in cost of the locks of the present project and the costs given by Equations 1 and 2 for the same lifts is due to the substitution of concrete for cut-stone masonry in the latter, thereby reducing greatly their cost. The lock masonry and lock-house for No. 31, being finished, are omitted from the estimates of costs in Table No. 3.

TABLE No. 3.

Number of locks.	Lift, in feet.	Cost (estimated) of present project.	Cost (estimated) by Equation 1.	Cost (estimated) by Equation 2.
4	8	$654 952	$474 975	$529 789
10	10	1 756 670	1 362 473	1 509 721
7	12	1 804 590	1 083 268	1 198 441
1	13	191 784	164 380	180 631
3	14	596 502	522 782	578 066
1	15	204 678	184 398	201 667
Total cost of present project.		$4 709 121		
Dams, abutments, houses, etc.		757 257		
Dams, guide piers, valves, gates, machinery, inspection, Lock No. 31.		11 302*	56 476*	63 270*
Total costs.		$5 477 680	$3 848 742	$4 251 585
Minimum costs by Equations 1 and 2, with economical lifts.			3 685 751	3 976 665

* Gates, valves and maneuvering machinery of Lock No. 31.

The minimum costs given by Equations 1 and 2 must be increased by the cost of the dam, guide piers, etc., at Lock No. 31, $56 476 and $63 270, respectively. These minimum costs will then be:

For 4-ft. navigation	$3 742 227;
For 6-ft. navigation	4 039 935.

The substitution of the economical lifts, 21.5 ft. and 23.2 ft. for 4-ft. and 6-ft. navigation, respectively, and the substitution of concrete for cut-stone masonry, would result in a saving:

For 4-ft. navigation	$1 735 453;
For 6-ft. navigation	1 437 745.

But the present project includes $407 201 for channel work, which is eliminated from the proposed economical project; therefore, the total saving would be:

For 4-ft. navigation	$2 142 654;
For 6-ft. navigation	1 844 946.

Comparing the costs given by Equations 1 and 2, using the lifts of the present project, with the costs given by those equations using the economical lifts, we find that there is a saving from the use of the economical lifts:

For 4-ft. navigation	$106 515;
For 6-ft. navigation	211 650.

Assuming that a lockage requires 20 minutes, there would result a saving in time over the time required for lockages under the present project:

For 4-ft. navigation (26 — 15) 20 = 3 hours 40 minutes;
For 6-ft. navigation (26 — 14) 20 = 4 hours.

The average cost of operating Locks Nos. 1, 2 and 3 on the Coosa River, for ten years past, has been for each lock:

For lock-master's wages	$600
For maintenance	1 000
Total	$1 600

The saving on this item would be:

For 4-ft. navigation (26 — 15) 1 600 = $17 600;
For 6-ft. navigation (26 — 14) 1 600 = 19 200.

Capitalizing these sums at 3%, there would result from this reduction of locks the equivalent of a permanent investment:

For 4-ft. navigation	$586 667.
For 6-ft. navigation	640 000.

The Government, therefore, could spend for overflowed lands the sums saved by the adoption of the economical lift, even though the saving to the public in reduced freight rates, due to decreased lockages, were not considered. These sums are as follows:

For 4-ft. navigation, 106 515 + 407 201 + 586 667 = $1 100 383.
For 6-ft. navigation, 211 650 + 407 201 + 640 000 = 1 258 851.

The uneconomical character of the present project is so apparent, from what has gone before, that in the further discussion of the subject it will not be considered. It should be stated, however, that the present project is designed to have 6 ft. of water over the miter-sills of the locks and 4 ft. in the river channel.

Water Powers.—It has not been the policy of the Government, heretofore, to utilize for commercial purposes the power developed at dams built for purposes of navigation; but the increasing use of electrical transmission of power, and the facility with which such transmission can be operated over long distances to places where the power can be used economically, will probably necessitate an early change in this policy. In view of these changed conditions, it will be well to consider here the effect which a judicious use of the power developed at the dams on this river would have upon the improvement from an economic point of view.

The low-water discharge of the Coosa River has been estimated variously at from 1 500 to 5 000 cu. ft. per second. Assuming the discharge at 2 000 cu. ft. per second, there could be developed at each dam:

With dams for 4-ft. navigation (21.5 ft.)....	4 887 H.-P.
With dams for 6-ft. navigation (23.2 ft.)....	5 273 H.-P.

Allowing 50% for losses and the maintenance of navigation, there would remain for commercial purposes:

With dams for 4-ft. navigation................	2 443 H.-P.
With dams for 6-ft. navigation.............	2 636 H.-P.

Assuming that the fall at the dams will disappear when the river below each dam rises to twice its height, which is approximately true, then, to overcome all fall at the dams, it would require:

With dams for 4-ft. navigation, a rise of 43 ft.

With dams for 6-ft. navigation, a rise of 46.4 ft.

Such rises on that part of the Coosa River under consideration are unknown.

The average yearly maximum rise at Lock No. 4 is 20 ft. Such a rise would leave a head as follows:

On dams for 4-ft. navigation, 11.5 ft.

On dams for 6-ft. navigation, 13.2 ft.

By providing additional water-wheels, the low-water power at each dam could be maintained.

The rentals of water-powers in the United States range from $5 to $45 per horse-power per year. Neglecting the fractional dams, and assuming that the Government leased or rented the power at all the others for the reasonable sum of $5 per horse-power per year, the income from this source would amount to:

From dams for 4-ft. navigation..............	$171 010;
From dams for 6-ft. navigation..............	171 340.

Capitalized at 3%, these sums would pay interest:

From rental of power at dams for 4-ft. navigation, on $5 700 333;

From rental of power at dams for 6-ft. navigation, on $5 711 333.

In other words, the Government could, from this source, pay interest on the improvement; pay operating and maintenance expenses; and have remaining a sum sufficient to pay interest:

With 4-ft. navigation, on 5 700 333:

$$\left(3\ 742\ 227 + \frac{24\ 000}{0.03}\right) = \$1\ 158\ 106;$$

With 6-ft. navigation, on 5 711 333:

$$\left(4\ 039\ 935 + \frac{22\ 400}{0.03}\right) = \$924\ 731.$$

These sums could be used in the erection of power plants at the dams or for other purposes.

It is not probable that the Government could rent the power at all the dams; but it is reasonable to assume that enough could be rented to pay operating and maintenance expenses and interest on the cost of the improvement.

The Alabama River.—The distance from Wetumpka to the mouth of the Coosa is about 14 miles; but as this part of the river is of the same character as the Alabama, for the purposes of this paper, it will be treated as part of that river.

The distance from Wetumpka to the mouth of the Alabama is 332.5 miles; the fall is 105 ft.

The banks of the Alabama are low, and the bottom lands on either side extend back 5 to 10 miles from the river. Like the Mississippi, the Alabama has banks that are caving constantly, and a bottom ever on the move; and unless movable dams were used, the pools would soon fill, leaving the river in worse condition than now, for constant dredging between locks would be necessary to maintain a channel. If dredging will have to be resorted to finally, then the construction of locks and dams, leaving out of consideration the danger to adjoining lowlands, would be more than a useless expense, and, therefore, the problem of improving this river resolves itself into a question of maintaining a low-water channel of the required depth by means of dredging.

The question of works of contraction is not considered, for experience on this and other rivers of the same character has been that such works merely move the obstructions, which they are intended to overcome, further down stream, and, that, to make such works effective, they would have to be built in such manner and places as to give the river, as a whole, a uniform slope and cross-section. The cost and maintenance of such a system would be prohibitive.

Unfortunately, no data exist upon which an accurate estimate of the improvement of the Alabama River can be based; but the writer believes, from his personal knowledge of this stream, that the estimates for dredging that follow are sufficient to maintain the channels proposed.

The following is an estimate of the annual cost of operation of one dredging plant:

One dipper dredge of 1½ cu. yds. dipper capacity	$15 000
Three dump scows	9 000
One steam tender	15 000
Total	$39 000

Assuming renewals every 15 years:

Cost per year for plant	$2 600
Repairs	300
Crew of dredge, 6 months	1 710
Subsistence, 6 months	600
Fuel for dredge, 6 months	500
Oil, waste, etc., 6 months	130
Tender crew, 6 months	1 830
Fuel for tender, 6 months	500
Subsistence, 6 months	600
Repairs, 6 months	200
Oil, waste, etc., 6 months	130
Two watchmen, 6 months	360
Contingencies, 10%	960
Total	$10 420

Assuming that six such dredging plants would maintain a 4-ft. channel and eight plants a 6-ft. channel, the cost per year would be:

For 4-ft. navigation	$62 520;
For 6-ft. navigation	83 360.

Capitalized at 3%, these sums would be interest charges on permanent investments:

For 4-ft. navigation	$2 084 000;
For 6 ft. navigation	2 778 667.

The total economical cost for the improvement of this system of rivers would therefore be:

For 4-ft. navigation:

Improving the Coosa River	$3 742 227
Improving the Alabama River, annual cost capitalized at 3%	2 084 000
Operation and maintenance of locks, Coosa River, capitalized at 3%	800 000
Total	$6 626 227
Deduct rental of power, capitalized at 3%	5 700 333
Cost to the United States	$925 894

For 6-ft. navigation:

Improving the Coosa River	$4 039 935
Improving the Alabama River, annual cost capitalized at 3%	2 778 667
Operation and maintenance of locks, Coosa River, capitalized at 3%	746 667
Total	$7 565 269
Deduct rental of power, capitalized at 3%	5 711 333
Cost to the United States	$1 853 936

Almost exactly twice the cost of the improvement for 4-ft. navigation.

But there is another factor entering into the problem: The freight rate. As coal will probably be the principal freight carried on this system of rivers, it is taken as the basis of comparison. The locks, as designed, will take at one lockage three barges and one towboat. This fleet is the basis of the following estimate:

		For 4-ft. channel.	For 6-ft. channel.
Cost of steamboat	per year	$667.67	$800.00
Cost of barges	"	500.00	600.00
Repairs	"	300.00	325.00
Interest on first cost at 4%	"	700.00	840.00
Insurance at ⅝ of 1%	"	75.00	93.75
Taxes	"	187.50	225.00
Two Masters	"	1 680.00	1 680.00
Two Engineers	"	1 200.00	1 200.00
Two Firemen	"	960.00	960.00
Six Men	"	2 160.00	2 160.00
Subsistence	"	1 200.00	1 200.00
Fuel	"	1 000.00	1 200.00
Supplies	"	200.00	200.00
		$10 830.17	$11 483.75

Cost per trip, thirty trips per year............	$361.00	$382.79
Capacity of fleet	848 tons	1396 tons
Cost per ton of freight.......................	$0.426	$0.274

Now, the value of any improvement is inversely as the first cost, the capitalized cost of operation and maintenance, the cost per ton freight rate; and directly as the capitalized investment resulting from the rental of power developed at the dams. Applying this rule to the present discussion, we have:

$$\text{For the value of 4-ft. navigation} = \frac{5\ 700\ 333}{3\ 742\ 227 + 2\ 084\ 000 \times 800\ 000 \times 0.426}$$

$$\text{For the value of 6-ft. navigation} \frac{5\ 711\ 333}{4\ 039\ 935 + 2\ 778\ 667 \times 746\ 667 \times 0.274}$$

Dividing the second equation by the first, we find that the value of 4-ft. navigation is to the value of 6-ft. navigation as 1 to 1.4621.

The tendency, in the United States, is to increase the navigable depth in rivers under improvement. Upon the system of rivers under discussion, at least, this is good practice, both from the point of view of the carrier and as an economic proposition. There is, unquestionably, an economic depth, just as there is an economic lift, but this paper cannot go further into a discussion of that phase of the problem.

In the final location of the locks on the Coosa River, it will be impossible, of course, to adhere to the economic lift indicated, but it will be possible to approach it, and the nearer the approach the more economical the improvement.

The writer has had access to excellent maps and profiles of the part of the Coosa River under consideration. The maps, however, do not show the topography of the adjacent country, and, therefore, it has been impossible to estimate the cost for levees and overflowed lands; but, as before stated in this paper, the banks are high, and in many places precipitous, and these costs would be comparatively small. This part of the Coosa is an ideal stream for locks and dams of high lift.

The writer knows of no good map of the Alabama River, and, as far as his knowledge goes, there is no profile in existence. The estimates for that river are made from his personal knowledge of the stream, and are believed to be safe.

The writer's investigations have led him to the following general conclusions concerning the improvement of rivers in the United States:

All streams, east of the Mississippi at least, and generally those west of that river, may be classified under two heads, which, for want of better names, will be called torrential and alluvial.

Torrential streams are those pouring down from the mountains and plateaus, and emptying generally into alluvial streams. They can only be opened to navigation by means of locks and dams.

Alluvial streams are those flowing through the coastal plain, and are always continuations of torrential streams. Except when the flow is insufficient to maintain the required navigable depth, alluvial streams should never be improved by means of locks and dams, for, with their caving banks and moving bottoms, the pools would soon fill, and constant dredging would be required to keep them open to navigation. Movable dams would remove this objection, but, with the present navigation on our rivers, their cost is prohibitive.

The use of isolated works of contraction on alluvial streams is a mere expedient, for their only effect is to move the obstruction further down stream. Of course, other contraction works could be built, until the obstruction was removed to the mouth of the river. Such extensive works of regulation would result in giving the stream a uniform slope and cross-section, and are an excellent method of improvement, except as to the cost, which would be enormous.

Finally, there is left the method of maintaining a temporary channel, during periods of low water, by dredging. This is the cheapest, and, with the present traffic on our rivers, is the one that should be used.

Our larger problems of river improvement embrace the study of the regulation of both torrential and alluvial streams in one and the same project. Every such system should be treated as a whole. It is as bad practice to have one part of a system improved for one depth of navigation and another for a different depth as it would be to have different gauges in the same system of railroads.

The time has come when the power developed by dams built for purposes of navigation should be used in the industrial development of the country. This being true, why should not the public at large, as represented by the Government, reap some of the benefits?

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

A HIGH-VOLTAGE POWER TRANSMISSION.

Discussion.*

By Messrs. F. O. Blackwell, P. H. Thomas, W. B. Potter, J. R. McKee and M. H. Gerry, Jr.

Mr. Blackwell.

F. O. Blackwell, Esq.—There are some features of electric power transmission which may be of interest. The first is that it is practically independent of distance. If a potential is used which is proportional to the distance, any distance can be reached. It does not matter much whether the power is carried across the room, or whether it is carried 100 miles—the same quantity of copper per horse-power is required for the same efficiency.

Having this independence of distance, the generation of power can be concentrated from several different places in one power-plant, for instance, from Helena and Butte, as has been done in this particular instance. The reverse can also be done; that is, the power can be brought from many different points and delivered to one place to be used.

Butte is also a good example of this. They have, at a water-fall near Butte, three electric power transmission plants, in addition to a 3 000 H.-P. steam-driven electric plant in the City of Butte. They bring 5 000 H.-P. 60 miles from the Missouri River, 2 000 H.-P. 67 miles from the Madison River, and 2 000 H.-P. 20 miles from the Big

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* This discussion (of the paper by M. H. Gerry, Jr., Assoc. M. Am. Soc. C. E., printed in *Proceedings* for January, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.

Communications on this subject received prior to May 23d, 1903, will be published subsequently.

Mr. Blackwell. Hole River, into the city. Three of the plants are working together, as if the generators were all in the same building, notwithstanding their great distance apart.

In some parts of the country they have as many as seven or eight steam- and water-power electric stations, perhaps 50 or 100 miles apart, all feeding into the same distribution system and working in unison like one plant. Power, to-day, is being delivered commercially to San Francisco and the neighboring cities from two water-powers 150 miles away. Temporarily, power has been transmitted 220 miles, by connecting the two transmission systems referred to.

Another characteristic of electric power transmission which is important is the high efficiency obtained regularly from electrical apparatus. If 80 or 90% efficiency is obtained from a steam-engine or a water-wheel it is a remarkably good result, but, in a large electric generator, as high as 97% can be obtained, and transformers changing from one potential to another have given more than 98% efficiency.

The efficiency of the power transmission is entirely a matter of how much copper is put in the transmission circuit, but it is seldom that more than 10% is lost in conductors, even with the long-distance transmissions already referred to.

Mr. Gerry does not mention the efficiencies of his apparatus and transmission, but Mr. Thomas is very familiar with the Missouri River plant, and has made many tests upon it. It would be interesting to hear from him as to the results of his experiments, and particularly as to the efficiency of the transmission to Butte.

Mr. Thomas. PERCY H. THOMAS, Esq.—The speaker has spent some time at the plant of the Missouri River Power Company, but, as he has not been connected with the company officially, he is not able to speak authoritatively of what has been done there. A few interesting points, however, might well be mentioned.

The speaker has not seen the figures giving the efficiency of the plant as a whole, but, for purposes of comparison, it can be imagined that power is transmitted from Canyon Ferry to Butte with as little loss as with a fair belt transmission of 15 or 20 ft.

Mr. Gerry has stated that, as far as he knows, this line has the highest voltage in commercial operation, and, probably, he is correct, though another plant which will use the same voltage is being installed and is about to be run.

This Canyon Ferry plant is remarkable in a number of ways: It is remarkable as to the country through which the transmission line passes; it not only crosses three mountain ranges, but one of these is the Continental divide—however, it is not the only line which crosses that divide. It is subject to very great changes of climate and temperature, and passes through extreme ranges of altitude. Lightning, in certain parts of the country traversed, is very severe, and Mr.

Gerry says he has noticed, near Helena, that the lightning—sometimes very severe discharges—generally comes out of a clear sky. The rain follows, but by that time the danger is over. At this plant there is great difficulty in getting intelligent electrical men of the various grades, as they are not very plentiful in that part of the country. Mr. Thomas.

In spite of all these difficulties, and many others, Mr. Gerry has succeeded very well. On March 7th, 1903, the plant will have completed a year's commercial operation. The continuity of service seems to have been very satisfactory, though the load handled, *viz.*, large motors, is of a type which is generally considered very difficult. The work in Butte has been the running of compressors, pumps, concentrators, etc. The street railroad is run by another plant.

The following is a feature which, perhaps, is somewhat interesting to civil as well as electrical engineers. Consider one of these 70-mile transmission lines charged up to the pressure of 50 000 volts; the energy stored therein, or that required to bring it to this condition, is about equal to 1 B. T. U. It seems remarkable that such a long line can be charged with so small an amount of energy and to such a high potential. Not only is this true, but it is also found, in practical service on such circuits, that the charging and discharging of this small amount of energy in some unexpected direction, as by accidental short circuits, cause some of the greater difficulties of operation.

During the summer of 1902 Mr. Gerry and the speaker made a number of tests on this plant, trying to determine some of the resulttant strains on the apparatus caused by a discharge of this British thermal unit in an unexpected direction, for instance, such an action as might be brought about by a tree falling across the wire.

Mr. Gerry almost has the record for continuous service on a transmission line at his Helena 12 000-volt plant. At no time during 24 or 26 months was the potential off the bus-bars at the substation in East Helena. That is a record which is difficult to equal in almost any kind of power work.

The question as to the possible effect of such a transmission line as this on long-distance telephone transmission is interesting. The telephone and high-tension lines are parallel for a number of miles. The power lines are 78 ins. apart and the telephone line, which is placed upon one of the two pole lines, is not much more than that distance from the lowest wires, but is pretty well up on the pole. Before Mr. Gerry started to operate his plant the man in charge of the long-distance telephone system feared that the high voltage would interfere with his work, and made a particular request that he be notified before the plant was started. By some oversight the plant was started without notifying him, and had been running for two weeks before he discovered it. Thus it can be considered that there is no very great danger—at least during normal operation—from the parallelism of such lines.

Mr. Thomas. Mr. Gerry has introduced one important feature in the construction of his pole line which may or may not be new. In running his wires over the country, he did not follow the slopes of the land in detail, but put in short and tall poles in such a way that the wires run on smooth grades and thus strains on the insulators and pins are avoided. In going over a summit he rounded off the top so that the highest pole carries no excessive weight.

Mr. Potter. W. B. POTTER, Esq.—How best to secure a maximum result with a minimum expenditure is an ever-present problem with the engineer. For short distances the economy of electrical transmission is limited by the mechanical strength of the transmission lines necessary for reliability; and a high economy of transmission can usually be secured at relatively low voltages. Over long distances the size of the wire may still be that necessary for mechanical strength, provided the voltage is increased correspondingly.

The installation described by Mr. Gerry is of particular interest as showing what can be accomplished at 50 000 volts, and the details and precautions taken to insure against accidental grounding of the transmission circuit. The speaker has been much interested and pleased to hear, through Mr. Thomas, of the reliability and efficiency of the service given. It is creditable to Mr. Gerry and the designing engineers of the power-station and substation apparatus that these results have been secured at what but a few years ago would have been considered an impracticable voltage.

Mr. Thomas has informed the speaker that, as far as he knows, the 78 ins. between transmission lines has proved ample to protect them against an arc being maintained in the event of its being established accidentally.

At one time it was considered that about 1 in. per thousand volts would be sufficient, but assuming, for mechanical reasons, a minimum distance of 18 ins., recent practice indicates that about 1½ ins. per thousand volts should be allowed, principally on account of the possibility of an arc being maintained between the wires in case it should be established accidentally. The speaker knows of several instances where the ubiquitous boy has derived much pleasure, and a display of fireworks, by throwing a wire across the lines. The arc thus established would be maintained and travel a considerable distance in the direction of the wind before being extinguished. The speaker believes it is a matter of record that, in one of the western systems, the transmission line was short-circuited, and the power-station shut down, on account of two large birds alighting on adjacent wires and endeavoring to communicate. They succeeded in establishing the connection, to their own undoing. It is perhaps a point worthy of consideration to take due account of the dimensions of the birds in the territory through which the lines may pass, and this suggestion is not necessarily confined to our western States.

Mr. Gerry mentions that the high-potential wiring within the stations is rubber covered, although the insulators on which it is mounted are evidently the main reliance for insulation. As the rubber covering on the wire can hardly be considered a protection, would it not be safer to run the wires through brick or cement compartments, in which event the wires could be left bare and thus lessen the quantity of inflammable material? Mr. Potter.

The term "load factor" has been mentioned several times, and it has been the speaker's experience that the exact meaning of this term is sometimes misunderstood. Many power-stations have reserve apparatus, which is not operated during the 24 hours, and he has found that there is a difference of understanding as to whether load factor is the percentage of average load to the machines in operation for the actual time they may have been running, or to the installed apparatus. The former is the usual and proper definition, and the speaker would suggest the term "station factor" to represent the average output, in percentage, of the total capacity of the apparatus installed.

The transmission of electrical energy is the solution and problem of electric power for the movement of traffic. The location of water-powers and the economy of steam-power necessitates generating power in large quantity and distributing it to the points of application. Instead of direct-current power-stations, 10 miles apart, and operating at a low load factor, alternating power-stations are now being built which transmit at high potential to substations 10 miles apart, more or less. Depending upon the character of service, the range covered by a given potential will vary from 1 to 2 miles per thousand volts; that is, if the service were subdivided and the cars of medium size, a 50 000-volt transmission, with the power-station located in the middle, would operate economically a railway 200 miles long, the limitation, of course, being the power required by the most distant substations.

The speaker believes that an unprecedented development in the railway field may be looked forward to during the next five years; and the problem of "high-voltage power transmission" will be one of the most interesting with which the engineer will have to deal.

J. R. McKee, Esq.—The speaker has the good fortune to belong to the same department in an electric company as that with which Mr. Blackwell is identified, and for all engineering questions has been in the habit of looking up to him. Mr. McKee.

The question: Can you transmit power electrically over very long distances? has been asked very frequently. It is only a very few years ago that doubt was expressed as to whether power could be transmitted economically over what are to-day such comparatively short distances as 10 or 20 miles.

The limitation to-day, in the handling of electricity for the transmis-

Mr. McKee. sion of power, is more of a mechanical than an electrical problem, and is confined largely to securing an insulator capable of withstanding the very high voltage necessary for economical, or, in other words, commercial, transmission over great distances, such as anywhere from 100 to 500 miles.

One particularly interesting feature in this plant is the use of a glass insulator for a 62-mile transmission over a wire carrying current at 40 000 volts. The speaker thinks there are but two plants in the United States where dependence is placed upon glass insulators for high voltage. One is at Provo, Utah, where, at times, a line has been coupled up for 130 miles, and where a voltage as high as 50 000 was used experimentally, although the normal operative voltage is about 40 000. The second plant transmits at 40 000 volts, 62 miles, from the Madison River to Butte, Mont.

Originally, the question of carrying current over long distances was largely dependent on the possibility of securing a transformer which would withstand a high voltage. Only a few years ago—say five or six, without stating it at all definitely—the electric companies did not care to undertake anything higher than 20 000 volts, and then their guaranty was that if they did not at first succeed, they would not stand for damages, but would try again. To-day, transformers are constructed and have been put into operation for as high as 100 000 volts, and, no doubt, as the art progresses, even higher potentials will be handled safely.

The attention of those who are interested in hydraulic work should be directed to the excessive cost which, unfortunately, is shown by so many of the first transmission plants, and which, in nearly every case, has been due to a misunderstanding of the hydraulic features.

The installation of water-wheels connected directly to the generators seemed to call for different methods or rules of calculation, as against those used in ordinary mill plants, where the load is not as variable and where the necessity for close regulation is not as great. The result has been that many of the earlier hydraulic plants, installed for the generation of electricity for transmission, have had to be overhauled, and, naturally, at very great expense, both as to actual expenditure and loss of time.

In one prominent plant the power-house is one of the most substantial granite structures to be found anywhere, and the hydraulic part of the entire plant cost nearly $500 000, but recently it has had to be altered, at a cost of not less than $100 000, because the water could not reach the wheels freely enough to take care of the varying load on the generators with sufficient promptness to give the necessary regulation.

In still another plant, costing more than $300 000 for the power-house, more than $75 000 has been spent in trying to get the water to the wheels more freely, the trouble being that the wheel-chamber was too small and the draft tubes not quite liberal enough in capacity to provide and carry away the water, respectively, when there was a sudden and large variation in the load, and to do it promptly enough to insure the regulation which is necessary in an electric plant. Mr. McKee.

Comparatively few people realize the extent to which water-powers are being depended upon to solve the question of cheap power, and also the rapid increase in the number of plants of this character. A very interesting installation is that at Salt Lake City, where, starting with a small transmission plant about 15 miles from Salt Lake City, they afterward put in a second plant, near Ogden, carrying the water through a 6-mile pipe line to the power-house and transmitting it 35 miles to Salt Lake City at 30 000 volts, an accomplishment which at that time (about six years ago) was considered very little short of wonderful. Both transmission plants are operated in synchronism with the steam station located at Salt Lake City.

At Butte, Montana, a plant installed on the Madison River, 62 miles distant, is transmitting over a line of aluminum wires at 40 000 volts, and delivering current to the bus-bars of the Butte Lighting Company in synchronism with current brought over another line of 21 miles from a water-power on the Big Hole River, and also with current generated in a steam plant in Butte.

The street railway and lighting system of the Cities of Seattle and Tacoma are operated largely by current brought 42 miles, over an aluminum wire, from a water-power on the Snoqualmie River. An additional water-power plant, located about 30 miles distant, is now being installed, in which 15 000 H.-P. will be generated for transmission to the same market. A third plant, of not less than 20 000 H.-P., to be installed on a third river, some 35 miles from Tacoma, is under consideration.

When these installations are complete, there should be no occasion for the use of any fuel whatsoever for the generation of power in either of these cities or in the locality, there being sufficient water-power to supply all the wants, fuel then being used only where it is required for heat, and the speaker is not absolutely sure but that the cost of electric current, due to the low cost of operating by water-power, may come down to a price so low that even heat can be supplied economically.

Los Angeles, California, one of the centers for oil—in other words, where fuel is cheap—has become one of the greatest transmission centers in the country. There are at present two water-power transmission plants delivering current to this market. One of these is located 85 miles distant, and the other about 20 miles. A third one, located approximately 110 miles distant, is being installed for 15 000 H.-P., and a fourth once, located about 125 miles distant, where they expect

Mr. McKee. to install 20 000 H.-P., is to be undertaken within the next few months. When all these plants are in operation, notwithstanding the low price of fuel at Los Angeles, it is probable that there will be very little steam power used in that city.

The different cities just referred to are only a few of the many in the United States which are being supplied rapidly with electric power generated from water-powers; and, inasmuch as current to-day can be carried distances of 100 to 200 miles economically, it is easy to comprehend how rapidly this method of supplying power will grow. In the spirit of prophecy, the speaker thinks it reasonable to anticipate that it will be only a few years, comparatively, before practically all the power used in manufacturing in New York State, north of a line drawn west from Albany, will be supplied by water power. The possibilities from water stored properly in the Adirondacks are such that, when fully developed, several hundred thousand horse-power of electricity can be generated therefrom for transmission purposes, and with the flood waters held back and stored so as to be released through the usual low-water periods, these water-powers can be made sufficiently uniform to justify their being depended upon for manufacturing purposes; so the rule will be that probably fuel in that section of the State will be used only where heating is a consideration.

With Niagara on the West, the St. Lawrence River on the North and the Adirondacks in the interior, the possibilities for power development are almost unlimited, and the assurance of cheap power equally promising. In the locations where the great developments just mentioned have been made, the natural supposition, particularly at Seattle, would be that there would be a great decrease in the consumption of fuel. This, however, does not seem to have been the case, because, as manufacturing has grown, the increased demand for fuel for use on locomotives and steamships—in other words, for transportation—seems to have more than offset any decrease in its use for manufacturing purposes.

Mr. Gerry. M. H. Gerry, Jr., M. Am. Soc. C. E. (by letter).—Of the greater uses of electricity to-day, perhaps the most important is that of an agency for the transmission of power. It is the connecting link by means of which mechanical energy, generated at distant points, is transferred and again converted into mechanical power under conditions favorable to economical application for commercial purposes.

Mr. Blackwell reminds us of the ease and reliability with which distant generating plants may be worked together, and of the high efficiency attained, as compared with all other methods of transmitting power. These are interesting facts, and are evidence of the desirability and flexibility of the agency under discussion.

Mr. Thomas speaks of the effective lightning protection and successful telephone service maintained on the Butte transmission. His remarks indicate that difficulties recently considered serious have been overcome, and that there is little reason to fear interruptions of the service from such causes on long transmission lines. Mr. Gerry.

Mr. Potter, in his interesting discussion, states that 1½ ins. per 1 000 volts should be allowed between wires on account of the possibility of an arc being maintained if once accidentally established between conductors. The wires on the Butte transmission are placed 78 ins. apart, but for reasons other than those mentioned by Mr. Potter. It is true that an arc will not be maintained at this distance in the open air, under 50 000 volts, nor will it be maintained at a somewhat lesser distance. The wires are so spaced as to control the brush discharges, the electro-static losses, and also to establish a certain line capacity. The rubber insulation of the wires in the station, to which attention is directed by Mr. Potter, is there for the purpose of reducing the brush discharge where the connections are near together, at the terminals of the transformers, and other apparatus. The thickness of the rubber, as stated, is ample to withstand the full electrical pressure. Brick and cement compartments, unless of very great size, are undesirable for high potentials, and even then do not represent the best form of construction.

In closing his remarks, Mr. Potter made an interesting allusion regarding the relation of high-tension electrical transmission to the problem of applying electrical power to the movements of traffic on the present steam railways. An electric railway, primarily, is an electrical power transmission. Its possibilities and scope have been limited in the past by reason of the use of direct current only, thus restricting the field of operation to comparatively short distances. A combination of alternating current transmission, with direct current distribution and application has met with some success in recent years in connection with electric railroading, but this must be regarded as but a temporary expedient, and not as a solution of the problem. There are no inherent reasons why alternating current may not be applied directly to railway service, and thus render possible the general use of electrical power for all classes of railways. There are, in truth, difficulties to be overcome, but they are in reality fewer than confronted the electrical engineers of even ten years ago, in applying direct current to city railway service.

Mr. McKee calls attention to the fact that transformers can now be obtained for electrical potentials up to 100 000 volts. This is certainly a high pressure, but there are no serious obstacles in the way of the use of this voltage on transmission lines where the conditions are such as to warrant the installation. The limit of electrical tension for the transmission of energy has not, as yet, been reached.

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SAND-BLAST CLEANING OF STRUCTURAL STEEL.

Discussion.*

By Messrs. Charles E. Fowler, William A. Polk, J. P. Snow, Theodore Belzner, Theodore Paschke, A. H. Sabin, Henry B. Seaman, E. A. H. Tays and George W. Lilly.

Mr. Fowler. **Charles Evan Fowler**, M. Am. Soc. C. E. (by letter).—This paper is certainly one of the most important that has ever been presented before the Society. The failure to clean the metal of steel structures properly before they are painted is the principal cause of their deterioration, and, practically, is the only cause which exists as a prejudice against them. While the bridge shops have, in most instances, endeavored to clean the steel properly before paint is applied, it has never been done satisfactorily, in the majority of cases, owing to the character of the plant used, and owing to the character of the help which it is necessary to employ on work of this kind. The laborers ordinarily employed as painters about bridge works are not possessed of a very high order of intelligence, and soon fall into the rut of glossing over and slighting their work. When they are discharged, and new ones put in their places, there is always a length of time for breaking them in, during which the work is not done properly, so that the writer believes that, necessarily, it must come to some such method as sand-blast cleaning at the bridge shops before painting is done, or else follow the lead of some European railroads, where the bridges are not painted until some time after erection.

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* This discussion (of the paper by George W. Lilly, Assoc. M. Am. Soc. C. E., printed in *Proceedings* for February, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.
Communications on this subject received prior to May 23d, 1903, will be published subsequently.

Mr. Fowler. The specifications of the Sheffield and Lincolnshire Railway Company for 1889 require that no portion of a structure shall be painted before erection, except such parts as are not accessible for painting afterward. Some time after the structure is erected, and the scale has all disappeared by rusting off, the metal is cleaned thoroughly and painted. Should this be done by the sand-blast process, and paint at once applied, there would be some surety of a proper protection from future rusting.

Many engineers seem to object to allowing rust to appear upon the steel at all, preferring to have the metal kept under cover from the time it is rolled until it is fabricated and painted, but anyone who has had experience with raw steel plates and shapes stored in a yard, will know that the mill scale, which very often is not removed otherwise, is rusted off, and the solid metal, although coated with rust, can be gotten at so as to be cleaned thoroughly and painted; whereas, if the metal is kept under cover, much of this scale remains on and is painted over, and in a few years flakes away from the metal, or rusting between the scale and the body of the metal goes on unseen.

In the writer's opinion, particular parts of bridges should be galvanized, in a great many cases, or protected by Barffing, so as to give them a protection once for all; but, in lieu of this, the thorough cleaning of existing structures by a method similar to that used by Mr. Lilly should be followed, and the coating applied directly afterward to protect the steel thoroughly. In such cases it will be possible soon to arrive at some definite idea as to which paint is really the best to use on bridges and steel structures.

While not directly a feature of Mr. Lilly's paper, it certainly is one which comes up in studying it, as to what kind of paint is really the best. The writer is not prepared to change his opinion, formed during many years as Chief Engineer of one of the large eastern bridge companies, that red-lead paint is the best that can be applied, regardless of the numerous paints which are advertised so loudly as the best for protecting steelwork. Red lead, used according to the Baltimore and Ohio specifications of 1896, by the addition of 10 oz. of lampblack to every 12 lbs. of red lead, can be handled as easily as any other paint. Next to this, for first-class work, are the various carbon paints put on the market by the standard paint companies.

While the writer has no data of his own, as to the cost of sand-blast cleaning, it appears from the paper that the cost can be reduced to a reasonable figure, and one which would warrant the use of the method whenever there is a large amount of cleaning to be done.

If this paper shall have served no other purpose than to have called attention in a forcible way to the need of thorough cleaning of steelwork before painting, it will have proved itself to be one of the most valuable papers ever presented for the consideration of engineers having to do with steel structures.

Mr. Polk. **William Anderson Polk**, Assoc. Am. Soc. C. E. (by letter).—The writer has read this paper with much interest, especially that part relative to cleaning the One Hundred and Fifty-fifth Street Viaduct, in New York City. During this operation the writer had the pleasure of devoting about one month's time to observation of the workings of the sand-blast, and found that it was the only power capable of removing the accumulated rust scale with despatch and economy. Moreover, it was the only method that was thoroughly efficient in preparing the surface for the tests of paints, that being the object for which the sand-blast was used on the viaduct.

To understand how thoroughly the machine did its work, it may be stated that on days in which the humidity was great (such days were frequent, the humidity registering often from 90° to 98°), the metal was no sooner cleaned than the gray color was changed by oxidation to a rusty brown. It was deemed expedient to apply the paint as soon as possible after a sufficient number of square feet (about 200) had been cleaned. This surface would comprise two buckle-plates, one on each side of the girder, and the section of the girder supporting these buckle-plates. The cleaned surface was protected from sand by a screen of sail cloth while the machine was being operated.

Notwithstanding this protection, a great deal of fine dust settled on the cleaned portion. This dust was readily taken up by the paint, however, and, in the writer's opinion, did no harm. One painter could finish in two hours the portion which had been cleaned by one nozzle-man in eight hours, under favorable conditions, *viz.*, in dry weather and with dry sand. Four nozzle-men could keep one painter busy, but, to accomplish this, the sail-cloth screen had to be moved frequently to places where protection might be necessary. On bridges at other places the writer has noticed that a screen was not needed.

The expense of cleaning the One Hundred and Fifty-fifth Street Viaduct was necessarily much greater than it would be to-day. The cost and the time of cleaning could be reduced very much by the addition of more machines.

For the purpose of preparing metal surfaces for painting, nothing has come under the writer's observation, during a period of ten years, that can approach the efficiency of the sand-blast machine. In order to have the best results from painting, it is expedient, nay, it is necessary, to have the surface absolutely free from rust, mill scale and grease; therefore the sand-blast will more than pay for itself in decreased maintenance and in furthering the lasting qualities of metal coatings.

Mr. Snow. **J. P. Snow**, M. Am. Soc. C. E. (by letter).—The Boston and Maine Railroad (with which the writer is connected) has used a sand-blast outfit for four seasons, but from its experience little can be added to the testimony given by the author. The mixers used are of the

Tilghman pattern, as shown by Fig. 1,* with a second hopper, so that sand may be fed continuously while the blast is operating. Mr. Snow.

The air is furnished by a Fairbanks-Morse gasoline compressor, with an 11-in. engine cylinder and a 14½-in. pump having an 18 in. stroke. Two, and sometimes three, open-topped galvanized-iron tanks, of 600 galls. capacity, each containing circulating water for cooling the cylinders, are used; these, and a small galvanized-iron gasoline holder, a boiler-iron air-reservoir, a sand-dryer, and pipes, hose, etc., complete the outfit.

The air pressure with this plant is from 15 to 18 lbs., which is very effective on weather rust not heavily scaled. Where the scale is caused by engine gases or by brine from refrigerator cars it is removed with hammers, chisels, etc., before applying the blast. It is thought that a greater pressure, as advocated by Mr. Lilly, would be more effective where the rust is heavy and the metal pitted. The pressure can be increased by exchanging the pump cylinder for a smaller one.

Usually, this outfit is loaded and unloaded by a car derrick. It is set up near the bridge to be operated upon, the water tanks are filled from the locomotive tender, a detachable shanty is put over the engine, sand is unloaded, the pipes are connected, and work is commenced. It requires only a few hours to set up the plant at a given bridge. It is desirable to have the sand-dryer as near the bridge as possible, but the engine should be 100 ft. away, or further, to get it somewhat out of the dust.

The sand should be clean and hard. For the highest efficiency, its fineness should depend on the kind of rust to be attacked. For simple weather rust, fine sand is the best. If the rust is heavy, the metal pitted and the surface hard to get at, coarse sand should be used. Where the work is over dry land, the sand can be used again several times. It gets finer each time it is used, but, as the impact against the metal breaks the grains of sand, they are sharp, and, until it becomes too fine, its effectiveness is rather greater than at first.

For drying sand a so-called Chicago dryer is used. Its action is similar to that of the dryer shown in Fig. 1, Plate XVII,† except that the dry sand escapes through an annular opening against the fire-box, which prevents, in a measure, the over-heating mentioned in the paper. This method of drying sand is very unscientific, however, inasmuch as the mass of sand in the hopper acts as a blanket to prevent the escape of steam from the lower portion next to the fire-pot, where there is the greatest heat. In fact, it is a good deal like trying to drive moisture out of a steam-tight box. A dryer, arranged so that the sand could fall over a series of inclined baffle-plates in a furnace, where the heated gases from the fire could pass over a thin moving sheet of sand and absorb its moisture, is a desideratum. The waste

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* *Proceedings*, Am. Soc. C. E., for February, 1908, p. 133.

† *Proceedings*, Am. Soc. C. E., for February, 1908, p. 147.

Mr. Snow. heat from the engine exhaust is enough to dry the sand in a properly arranged dryer, but there are practical difficulties in using it. The exhaust from an explosion engine should be free and close to the engine, to obviate back pressure; but, to save the running parts, the engine should be at some considerable distance from the sand. Again, it is frequently desirable to dry sand when the engine is not running; therefore, on the whole, it seems best to use an independent dryer.

Some difficulty is experienced from moisture carried by the condensed air. A very little dampness will cause the sand to clog at the lower valve, as mentioned in the paper; but, with drips at the air reservoir, and no sags in the lines of air pipes, the trouble is not great.

In cleaning a long bridge the air has been carried as far as 900 ft. from the reservoir. A 3-in. pipe is used, and there is very little reduction in the pressure from the reservoir to the mixers.

The operation of painting is similar to that described by Mr. Lilly. On overhead bridges, which suffer from the blast action of the locomotive smokestacks, it is not considered a disadvantage to have the sand get into the raw paint. Two coats are applied, and the portion directly over the centers of the tracks receives three coats. If the first is well filled with sand the result is a thick, gritty coat, which has considerable power to withstand the blast of hot sparks from the stacks.

With the engine described, three mixers and nozzles are used. The force required is generally a foreman and six men; three on the nozzles and three drying sand and feeding it to the mixers. The writer has no reliable statistics as to cost. The figures given in the paper are fairly comparable with average results obtained, but many jobs cost more on account of the difficulty of getting at the parts to be cleaned. The question simply resolves itself into a choice between letting the metal waste away at its own rate, or paying the cost of cleaning it with the sand-blast. Where iron has become heavily scaled by locomotive gases, brine from beef cars, or sea water, it is simply impracticable to stop corrosion by any method, known to the writer, other than the sand-blast.

Mr. Belzner. THEODORE BELZNER, Jun. Am. Soc. C. E.—In this paper Mr. Lilly has carefully covered the ground, and has left little to be added except practical experiences in the same line. A number of his recommendations should be carried out, and, if criticism were to be made, it would have to be said that he does not place sufficient emphasis on some of his recommendations.

The speaker will endeavor to relate the experience gained in the sand-blast cleaning of steel on the Rapid Transit Subway, in New York City.

Owing to the magnitude of the Rapid Transit Subway work, steel had to be ordered largely in advance from the manufacturers, who in this case were the American Bridge Company. Such steel as columns and girders of standard size and design were ordered, so as to facilitate the output at the mills. Large quantities were received, and lay for from eighteen months to two years, piled high in the streets and at the yard at the foot of Forty-second Street, East River. This steel was exposed to the inclemency of the weather for that period. When the sub-contractors were ready to use the steel it was found that the paint had worn off considerably, and a part of the steel was corroded. It was determined to clean and repaint before erection such parts as were to be exposed in the structure, and all abutting and connecting parts which were not to be embedded in concrete. S. L. F. Deyo, M. Am. Soc. C. E., Chief Engineer for the Rapid Transit Subway Construction Company, acting on the recommendation of William Barclay Parsons, M. Am. Soc. C. E., Chief Engineer for the Rapid Transit Commission, then gave the order to the sub-contractors to clean the steel with the sand-blast. Mr. Belzner.

Before taking up the work in detail it should be stated that the various sub-contractors had established air-compressing plants on their various sections, thus having their line covered with compressed-air pipes.

A large quantity of steel was piled at Canal and Elm Streets, and work was commenced there, but was found to be such a nuisance to the tenants of surrounding buildings and to traffic that it was moved down into the partly-finished subway. Here the dirt and sand became a hindrance to the workmen, and the work was moved to Bond and Elm Streets. Here, again, it proved to be such a nuisance to the public and to traffic that the operation of the blast was confined to night hours. Work was then carried on at this point for a long time until the street was cleared for paving. The plant was then moved to Forty-second Street and the East River, where, again, work during the day was found to be objectionable to the neighborhood, and the work is now being done at night.

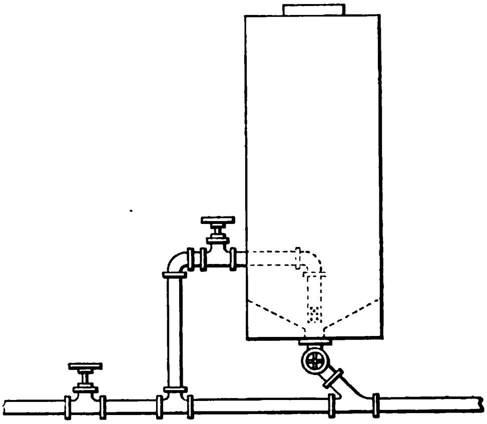
The plant, after being moved to Forty-second Street and East River, was entirely rearranged, and in such a way as to obtain much better results than those obtained previously. The size of the pipe from the condenser to the blasts was increased to 1½ ins., and a much greater pressure was obtained, thereby largely increasing the quantity cleaned. The tanks were about 200 ft. from the power-house. The arrangements for drying and storing sand ready for use were also improved, and the handling was facilitated considerably by the use of the crane in lifting and piling the steel.

Two plants are at work: That for The Degnon-McLean Contracting Company consists of four tanks of double-row, riveted, extra

Mr. Belzner. heavy, ordinary kitchen-boiler, 14 ins. in diameter and 4 ft. 10 ins. long, the interior arrangement of which is shown in Fig. 4. The plant in use by the Holbrook, Cabot and Daly Contracting Company consists of two tanks having a similar interior arrangement.

Although four tanks were erected for The Degnon-McLean Contracting Company, only two are in use, as a rule, the extra tanks being kept in reserve in case of any trouble, thereby preventing any interruption of the work.

The simplicity of the design of these sand tanks should recommend itself to engineers, because any mechanic can look after them, thus avoiding the use of patented devices such as described by Mr. Lilly.



SECTION OF SAND-BLAST TANK.
FIG. 4.

Great care has been taken in the selection of the sand. That coming from the shores of Long Island Sound has proved to be the best for the purpose desired. The arrangements made for drying the sand consist of an open brick flue, about 3 ft. wide and 20 ins. high, on which are placed two iron trays. These trays are of ¼-in. iron, and each is 6 ins. deep, 3 ft. 6 ins. wide and 4 ft. long.

Great care should be taken in drying the sand. It should be turned over continually, which in this case had to be done by hand. When dry it should be removed from the pans at once, and not allowed to burn or bake, for in that case when it came into impact with the steel it would be brittle, and, battering into fine dust, would not remove the rust. Sand dried properly and carefully can be used two or three times with good results. In a permanent plant, a rotary dryer, over a fire, or supplied with a hot blast, could be used very economically, and the drying would be more uniform.

Mr. Belzner.

A section, about 6 ins. in diameter, was cut out of the crown of each blast tank and a screw cap fitted to the opening. This is removed while the tanks are being filled. The sand is passed through a fine wire mesh before being poured into the tanks, so that nothing can pass through that will tend to choke or obstruct the valves and fittings.

The outlet for the sand is at the bottom and center of the tank, and is of 1½-in. pipe connecting below with the air-pipe at an angle of about 45 degrees. About 6 ins. above the outlet another connection is made through the side of the tank by a 1-in. pipe extending to the center of the tank, with an elbow, the end looking down into the outlet. This pipe and elbow are perforated with small holes, and air under pressure, and controlled by a valve, is admitted so as to keep the sand slightly agitated, thereby facilitating its flow through the outlet.

The sand flows from the tanks through a flexible rubber hose of 2½ ins. internal diameter, to the end of which is attached an ordinary pipe reducer to receive the nozzle; it passes out at a uniform pressure of 65 lbs. per square inch. This pressure is furnished from the power-house erected for the purpose of supplying power for the work being done on Park avenue and Forty-second Street.

In front of the tank a platform of 2-in. timber, 25 x 50 ft., was built. On this the pieces of steel are placed side by side, and when the upper sides are cleaned, the pieces are turned over and the opposite sides cleaned. When cleaned, the steel is painted, and then removed and piled by the crane.

Nozzles of extra-heavy, ½-in. gas pipe, varying from 7 to 18 ins. in length, have been used; but it has been found that the 12-in. lengths are most effective. The life of the nozzles varied with the sharpness of the sand, the temper of the pipe material, and the air pressure, but, on the average, lasted 1½ hours. The nozzles were generally worn through, about 2 to 3 ins. from the reducer, owing to the deflection of the sand leaving the large hose, passing through the reducer and then striking the nozzle at that point. This condition would suggest that a special, graduated coupling from hose to reducer be devised, so that the sand would pass through at a uniform rate without meeting a break, thus avoiding the deflection.

The force consists of a foreman, who regulates the valves controlling air and sand, two nozzle-men who direct the blast (these men had to wear goggles to protect their eyes), two men to dry the sand, attend to the fire and keep the tanks filled, and also, one laborer, who assists the nozzle-men in handling the hose.

As the yard covered a large area and the steel was distributed all over it, it was a question whether it would be more economical to have a portable blasting machine or to make it stationary and use the crane and traveler for the purpose of handling materials. It was finally de-

Mr. Belzner. cided to make the plant stationary and use the crane for collecting and subsequently piling the steel.

The material cleaned consists principally of bulb angle-columns, I-beams for wall-columns, roof I-beams, knee-braces, rivets, plate-girders, splice-plates, grillage-beams, and angles. Plate XXXVI shows a girder before and after being cleaned by the sand-blast.

The question of the advisability of cleaning the steel before it leaves the shops could well be taken up. Were the mill scale and dirt removed before the steel is painted, the protective coating given it at the shops would undoubtedly prove more effective in the prevention of corrosion than by the present methods.

Such an adjunct to the manufacturing plants, if properly laid out, could resolve itself into practically first cost. If automatic devices for drying the sand and then feeding it to the blast were devised, much labor and time would be saved. Still more, the nozzles of the blast could be in a fixed position, and a rolling table provided for the steel. An automatic device for spraying the paint on the steel might also prove an advantage.

In preparing this discussion the speaker had the assistance of Mr. R. S. Fowler, Junior Assistant Resident Engineer, who also furnished the data, photographs and drawings. The speaker's thanks are also due to Mr. J. J. Shannon, Inspector for the Rapid Transit Subway Construction Company, for useful suggestions.

Mr. Paschke. **Theodore Paschke**, M. Am. Soc. C. E.—Before giving any figures which can serve as a basis for comparison with those given by Mr. Lilly, as to the cost of cleaning some of the structural steel for the New York Rapid Transit Subway, as described by Mr. Belzner, it will be necessary to state briefly and as nearly as possible the actual conditions, rather adverse in some cases, under which the work had to be done.

When it became evident that the shop coat of paint had been practically destroyed by long exposure, and that it was necessary to arrest the destructive work of corrosion which had set in, the Subway Construction Company, in obedience to orders from the Rapid Transit Commission, assumed the responsibility of the work, and arranged with its sub-contractors on Sections Nos. 2 and 3 to perform the work of cleaning the steel and replacing the shop coat of paint, as an extra, at cost plus the usual percentage allowance customary in such cases. The sub-contractors for Section No. 2 (comprising the Elm Street section) are the Degnon-McLean Contracting Company; for Section No. 3 (comprising Lafayette Place and Fourth Avenue) the Holbrook, Cabot and Daly Contracting Company. The work was done by them subject to the inspection of the engineers of the Rapid Transit Commission.

The work was started by hand cleaning, that is, by hammer,

PLATE XXXVI.
PAPERS, AM. SOC. C. E.
APRIL, 1903.
BELZNER ON
SAND-BLAST CLEANING OF STEEL.

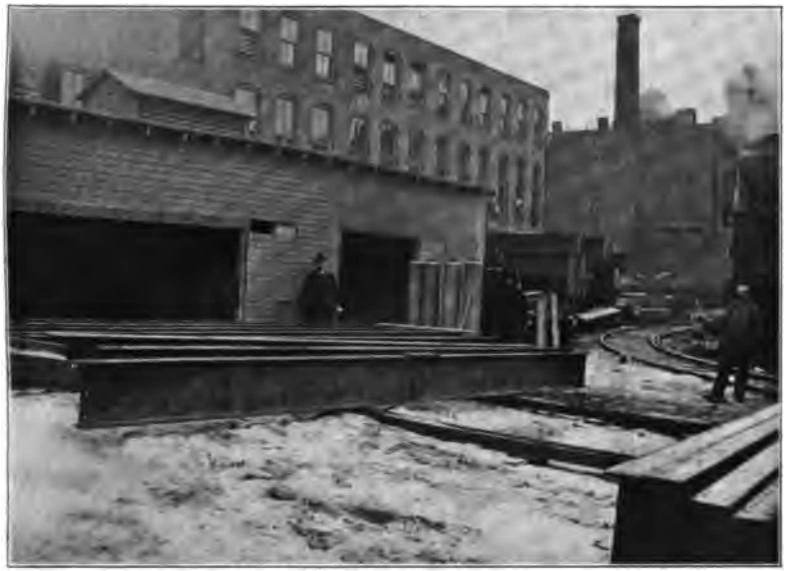


FIG. 1.—FIFTEEN-INCH I-BEAM, BEFORE BEING CLEANED WITH THE SAND-BLAST.

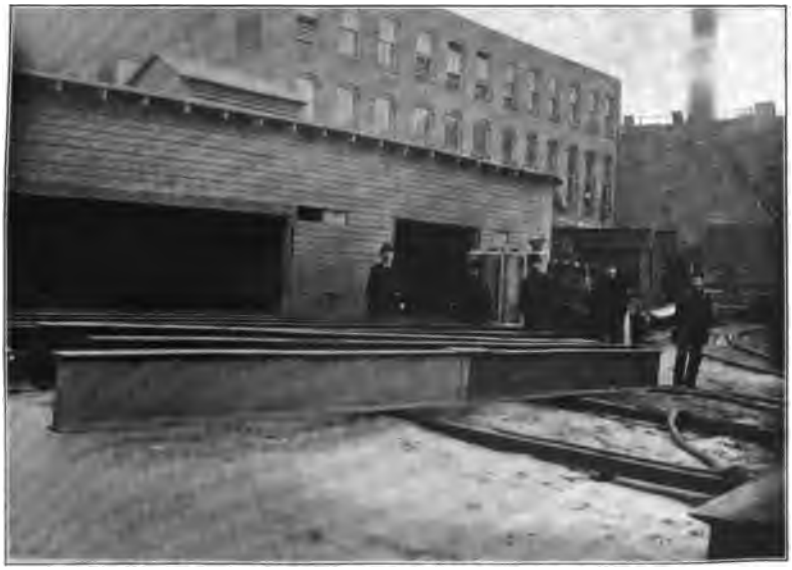


FIG. 2.—FIFTEEN-INCH I-BEAM, AFTER BEING CLEANED WITH THE SAND-BLAST.

Mr. Paschke.

scraper and wire brush. This did not prove satisfactory either in point of cost or in efficiency, and involved the sub-contractors in an almost continuous controversy with the inspectors. It was suggested that the sand-blast process be used, and in view of the fact that the sub-contractors had compressed-air pipes along the line of their work, thus facilitating the installation of such process, Mr. Deyo, Chief Engineer of the Subway Construction Company, readily assented.

On the Elm Street section the steel to be cleaned was piled at various points along the street. Mr. Belzner has described the attempts made to locate the sand-blast at the various piles of steel. Thus, the operation of the blast had to be confined to one point and carried on during night hours. The steel had to be brought to the sand-blast, and there manipulated by hand entirely. The arrangements for drying the sand were primitive, owing to the temporary conditions of the work. The first cost of installation of the blasts, their various removals and transfers from one point to another, was added to the cost, tending to increase this abnormally.

At the Forty-second Street yard, where the Fourth Avenue steel was piled, the conditions were somewhat different. The yard is 200 ft. wide and 700 ft. long, and is provided with a network of tracks and a traveling crane with a flat car for the handling of the steel. Here, a plant on a little more permanent basis was erected, and the steel handled and brought to it from the various points of the yard by the traveling crane. Although these conditions were more favorable than on Elm Street, they may be considered rather exceptional for such work.

In the work on Elm Street and at the Forty-second Street yard about 5 000 tons of steel have been cleaned by this process.

But all this steel was not cleaned over its entire surface; only about one-half being cleaned entirely, one-quarter had 75% of its surface cleaned, and on the other quarter about 50% of its surface underwent the sand-blast process, for the reason that on the remaining surface the shop coat was found to be in good condition.

In the case of the work at the Forty-second Street yard, the total cost, including the repainting, amounted to from $3.50 to $6.50 per ton, the higher cost being due to the greater adversities experienced during the winter months. In the case of the work done on Elm Street, the cost ranged about $1.50 per ton higher. It should be stated that the eight-hour basis for a day's work is in vogue throughout the subway work, and that the entire work of cleaning and painting had to be conducted in the open, exposed to all the vicissitudes of the weather, resulting often in the necessity of reblasting the steel, before being able to paint it.

It would seem from these figures that in the case under consideration the use of the sand-blast did not result in any direct economy

Mr. Paschke. over hand cleaning. However, the results obtained were infinitely superior. The steel, after emerging from the sand-blast, presented a beautiful appearance, in fact, being fit to go into an electro-plating bath.

The experience had here with the usual customary shop coat as a protection for the steel against corrosion before erection seems to confirm Mr. Lilly's contention for the desirability of applying the sand-blast to structural steel at the works, after manufacture and before the application of the shop coat. Notwithstanding the high cost of the work performed in the present instance, which was due to exceptional and rather abnormal conditions, the speaker fully believes that the sand-blast process can be used at the works to advantage, and at a cost not exceeding that given by Mr. Lilly.

Mr. Sabin. A. H. Sabin, Assoc. M. Soc. C. E.—Although the speaker has never actually conducted any sand-blast work, he believes that it was at his suggestion that the sand-blast was used upon the One Hundred and Fifty-fifth Street Viaduct some years ago. He has, however, been interested for years in this matter of the proper cleaning of structural steel before painting, and can agree fully with what Mr. Lilly says about its great importance. It is a waste of money to buy even the best of paint and spend a large sum for labor in applying it to a rusty surface.

More than a hundred years ago, one of the great early English engineers—Smeaton—remarked that he had observed that if rust had once started on the surface of the iron, it made no difference what varnish or paint was applied to the surface, the rusting would continue to go on progressively under the paint. That conclusion has been reached by every man who has investigated the subject honestly and disinterestedly.

Mr. Paschke has stated when the steel had been cleaned with the sand-blast it was fit to go into an electroplating bath. That is right. It will be observed that it is assumed that if a piece of metal is to be electroplated it has to be clean, down to the surface of the metal; none of the oxide or scale must be left on the surface. It is equally true that to apply a vitreous enamel, such as on granite earthenware, etc., in the first place the surface of the metal must be obtained on which to put the enamel. All such ironwork is cleaned usually by pickling. To apply a varnish enamel, as in the case of a bicycle frame, it is absolutely necessary to do the same thing; otherwise the enamel, or the electroplate, will come off in time, because the rate of expansion of the scale is always a little different from that of the iron, and in time the scale will loosen up.

Now, the speaker is a paint man, and has had an experience of a good many years. He believes that paint sticks on iron in exactly the same way that anything else does, and the conditions which favor the

Mr. Sabin. adhesion of other things favor the adhesion of paint. If it is necessary, if it is absolutely indispensable, as all agree, to have all these other coatings applied to the actual surface of the metal, and not to any scale or rust, or anything of that sort, it is also desirable to apply paint directly on the iron.

There are plenty of people who think—no doubt many who think honestly—that the oil and paint will mix up with the iron rust and keep out the air, and in that way the corrosion will be stopped. The trouble with that theory is that the paint and varnish are not absolutely non-porous. If they were it would be all right. Neither is cement or concrete non-porous, and when the corrosion gets under way, its action is very rapid. That is a chemical question which is not worth while discussing now as it has been beaten over a good many times, and probably most of those who are interested in the subject are thoroughly familiar with the theory of the matter.

It is comparatively easy to keep iron free from rust when it is clean, but, after the rust has started, it is very difficult to stop it or to clean it away from the metal.

The speaker had hoped that this paper might bring out a discussion from somebody who had had experience in cleaning iron by dipping it in acids, or "pickling." Of course, that is not sand-blasting, but the result is what is desired. The speaker is not aware that, in this country, any structural metal-work has been cleaned by pickling, but a great deal has been cleaned in Europe, some of it many years ago, and it is being done now, with most excellent results. Of course, the result of a first-class job of pickling is just the same as the result of sand-blasting.

One of the advantages of the sand-blast, not mentioned by Mr. Lilly, is that it leaves the iron not only clean, but dry. The process of pickling leaves the surface of the iron wet, and it has to be dried. It would be difficult to apply the process of pickling to structural work in place, such as an erected bridge, or anything of that sort, but it would have been extremely interesting to have had an idea of the comparative cost of cleaning the steel for the rapid transit work by pickling, as compared with the sand-blast.

There is probably a thousand times as much iron and steel cleaned by pickling as is cleaned by the sand-blast. There is an immense amount of it done. Those who are not familiar with the subject have no idea of the extent to which it is practiced, but, in this country, it has not been applied to structural steel.

There is a feature which did not appear in Mr. Snow's admirable discussion. Mr. Snow has really had a great deal of experience in the use of the sand-blast on bridges, and has told the speaker that, usually, he did not clean the whole of a bridge with the sand-blast, as that is regarded as rather expensive. Such parts of the bridge as are

Mr. Sabin. specially liable to corrosion are cleaned by the sand-blast, and other portions, which are not so subject to deterioration, are cleaned in a less thorough and less expensive manner, for the reason that those portions which are most liable to corrosion will, in spite of the greatest care that can be taken, probably rust out as rapidly as the other portions with somewhat less care, although, of course, a man who is sufficiently interested in the matter to do sand-blasting is not going to have any poor work done. This feature, however, is worth remembering.

It may be regarded in another way. If a man sets up a sand-blast plant to clean a bridge, and has all his apparatus and his gang of men to do it, and only cleans, say, one-quarter or one-third of the bridge, he cannot do that quarter or third of the bridge as cheaply per square foot as he could clean the whole bridge, so that the cost per square foot is a great deal higher than it would be if he were cleaning the whole work, and for that reason any figures that he gets must be taken with regard to that fact.

In reference to the possible danger of cutting away the iron: Mr. Lilly observed that it was immensely more difficult, and required a great deal more power, to remove a hard compact scale than to remove ordinary rust. Now, the difficulty of cutting away tough, hard steel is immensely greater than that of cutting away the hardest kind of rust, and the speaker was told—this was not his own experience—by the manager of the Wolff Bicycle Company, some years ago, when they were using the sand-blast for cleaning the frames of bicycles, that before they purchased their sand-blast apparatus, they were apprehensive about cutting away the metal, because the tubing they used was very thin; and to test the matter they held a piece of tubing in the current from the sand-blast machine for twenty minutes continuously and then, with a micrometer scale caliper, which would show a thousandth of an inch, were not able to find any diminution in the diameter of the tube. Consequently, they thought that they were safe in using it; and if that is the case, there should not be very much apprehension as to cutting away the steel.

Mr. Seaman. H. B. Seaman, M. Am. Soc. C. E.—There seems to be little to add to the discussion which has already taken place, except, possibly, to mention the dangers of the misuse of the sand-blast. It is undoubtedly a most efficient method of cleaning iron, especially where the rust is badly caked, or is in inaccessible corners and cannot be reached by hand; but where the rust is slight, and especially where surrounded by elastic paint, the excessive use of the sand-blast may prove more injurious than the rust which it removes. The sand-blast will remove the rust quickly, but if continued long enough to remove the elastic paint, which requires considerably more time, the parts which were rusted will be worn deep and pitted, and when the whole surface is bright and smooth, and acceptable to an enthusiastic inspector, more metallic iron may have been removed than would be the case after several ordinary coats of rust. Furthermore, the naked iron, as left by the sand-blast, will rust much more quickly than when the mill finish is left. Mr. Seaman.

An illustration of the danger of overdoing the sand-blast occurred recently, under the supervision of an ardent, but well-meaning, inspector. Four columns, which had been similarly exposed to the weather while stored in the same pile awaiting erection, were brought out and laid side by side to be cleaned by the sand-blast. After 3½ hours of the sand-blast two of these columns were stripped absolutely clean of rust and paint, and of all sign of the original mill surface; finished, in fact, clean enough for electroplating. The work could not have been done more thoroughly if performed in a laboratory for experimental purposes. The remaining two columns were then cleaned of rust and dirt, but all good paint was left on. This required 45 minutes, and the columns were left in better condition than the first two, at about one-fourth of the expense.

The theory that iron must be cleaned to a white surface before being painted does not seem tenable. The thin coat of black oxide formed after rolling is of itself a valuable protection, being the most permanent form of iron oxide, and even when the iron is tinted brown with rust it is not clear why the paint which would protect the iron from rusting, will not in like manner prevent the rust from progressing, excepting, of course, where the rust is so thick as to prevent adhesion of the paint to the iron. Where the sand-blast is used it is necessary to paint at once to prevent corrosion.

Aside from the commercial or scientific value of sand-blasting, there is a very serious question of its effect upon the eyes and lungs of the operator. Its use in connection with bridge shops would seem, not only objectionable on account of its disturbing effect upon the other operations, but, as already mentioned, would remove the black oxide of manufacture, which is its natural protection. Any scale which may be formed after rolling is quite thoroughly removed in punching and handling through the shops.

Mr. Tays. E. A. H. Tays, M. Am. Soc. C. E. (by letter).—The writer has noticed that the means of drying the sand, as described by Mr. Lilly, were very crude, and the idea suggested itself that they could be improved.

The following suggestions may be of service in enabling those of the profession engaged in that work to improve upon the present practice in that line.

Where temporary plants are required, a sheet-iron bed, 8 ft. long, 4 ft. wide, or wider, made hollow, about 4 ins. high, or, with sufficient room for a 2-in. steam coil, or line, of pipes, set on a frame 3 ft. high, would do the work; the steam coil being used to pass the exhaust

Mr. Tays. steam through; or, the exhaust could be turned directly into the hollow bed. This bed can be made of the thinnest sheet or galvanized-iron, and should have a 2-in. flange on the sides, but none at the ends; and it might be set with a slight fall, to facilitate drawing off the sand with a hoe or rake at the lower end.

In large, stationary plants, a cylindrical dryer, on the lines of the Howell-White roaster, or of the type of the ordinary ore-dryer used in dry-crushing mills, would seem to be just about the thing. It could be made of much lighter material than the ore-dryer and much smaller in size.

This dryer is a revolving cylinder, larger at one end than at the other, and is heated by wood or coal, the heat passing down the cylinder. The sand is fed into a hopper at the small end, and the revolutions of the cylinder, say five per minute, gradually pass it out at the other, thoroughly dried.

These observations may enable some of those who are working in this line to devise an economical as well as efficient sand-dryer; if so, the object of these remarks will have been attained.

Mr. Lilly. George W. Lilly, Assoc. M. Am. Soc. C. E. (by letter).—Mr. A. H. Sabin has called attention to the fact that one of the great advantages of the use of the sand-blast is the dry condition of the metal after being cleaned by it. This is certainly a great advantage and essential to the best efficiency of the preservative paint. It is also true that, unless the paint is applied soon after the cleaning is done, moisture is likely to accumulate on the steel, especially if the atmosphere is nearly or quite saturated with moisture. It has been urged, therefore, that the paint should be spread within the shortest possible time after the cleaning is done, and in no case should any cleaned surface be permitted to remain over night without a coat of paint upon it. Some delay, say 2 or 3 hours, may be permitted when the atmosphere has only slight humidity. When the atmosphere is surcharged with humidity the moisture may gather on the steel immediately after it is cleaned. At such times no cleaning or painting should be done.

While, as Mr. Snow says, it may be considered no disadvantage to have some sand get into the raw paint, if it is to be subjected to the blast action of locomotives; yet screens are sometimes of advantage to prevent too large a quantity of sand getting into the paint in the buckets before it is applied to the steel. At times the wind may send large quantities of sand back to the painters and the paint become so filled with sand that it rolls under the brush and cannot be spread properly. It is not often found necessary, however, to use the screens between the nozzle-men and the painters.

The writer admits freely that neither the pan nor the hopper form of sand-dryer is scientific or highly efficient. A rotary dryer is, no doubt, a good form, where power is available and the exhaust steam

Mr. Lilly.

may be utilized; but, at Columbus, Ohio, the power was from 1 200 to 2 100 ft. from the places where the cleaning was done. No doubt, a better sand-dryer can be devised than any of those which have been used in the work done heretofore.

Mr. Seaman urges caution against the danger of extending the use of the sand-blast too far and cleaning steel which is already in good condition to receive the paint. The same thought was suggested in the paper, and it is certainly true that good judgment should be exercised. The intelligent application of the process in the cases where it is required to prepare the surface of the metal so that the paint, when applied, will adhere properly and give good protection against further corrosion is all that is contended for. For the reason that some of the paint was still good, some parts of the viaducts named in the paper were not sand-blasted down to the metal surface, but rust spots only were cleaned away. The parts where rust and corrosion have destroyed the paint, and where the paint is dead and disintegrating, should be cleaned thoroughly; and the sand-blast seems to be the best process for such purpose.

The black or magnetic oxide spoken of by Mr. Seaman is nearly all destroyed by the rusting of the metal before the shop work is completed, save, perhaps, where the thicker scale has formed. That all the mill scale is removed by the processes through which the steel passes in the shop is, the writer believes, putting the case rather too strong.

Mr. Fowler suggests permitting the metal to rust somewhat, in order to remove scale as far as possible, and then cleaning it thoroughly before painting. It will be observed, if a careful examination of old structures be made, that in many cases the mill scale has been covered with paint, and corrosion has attacked the steel and loosened the scale, making centers from which rust will extend.

The composition of mill scale, or, at least, of its characteristic, porous inner layer, makes it reasonable to expect just such results. Mill scale forms in two layers, the inner one being represented approximately by the formula $6\,Fe\,O + Fe_2\,O_3$, and, as stated, is very porous and brittle. The outer layer contains a larger but varying proportion of $Fe_2\,O_3$. The air and moisture contained in this porous scale tend to destroy the paint spread over it by starting corrosion. This scale is magnetic. A galvanic action is said to be set up around the edges, and corrosion commences there and afterward extends under the scale and outward under the paint. It is considered important, therefore, that the mill scale be removed by some efficient means before the first coat of paint is applied.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

NOTE ON THE COEFFICIENT OF ELASTICITY OF CONCRETE AND MORTAR BEAMS DURING FLEXURE.

Discussion.*

By E. J. McCaustland, Assoc. M. Am. Soc. C. E.

Mr. McCaustland. E. J. McCaustland, Assoc. M. Am. Soc. C. E. (by letter).—It is quite evident, from a study of the tests on concrete and mortar beams reported by Mr. Falk, that, in so far as they prove anything, they prove that the coefficient of elasticity of concrete or mortar does not increase materially with age. However well established it may be that the strength of mortar made from Portland cement increases with the lapse of time, it is not established anywhere, as far as the writer is aware, that the coefficient of elasticity is affected in a like manner. For the practical purposes of the engineer, it is of more importance to know the properties and to be able to forecast the behavior of mortar and concrete during the earlier stages of the hardening process. This is the critical period, in many classes of work, when loads must be borne by the structure before time is given for an advanced degree of hardening. Nevertheless, all reliable information regarding this important structural material is worthy of record.

These tests are of interest, and afford valuable information, despite the fact that the varying mixtures give no opportunities for comparison, or for average results. This lack of comparison leaves many

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* This discussion (of the paper by Myron S. Falk, Jun. Am. Soc. C. E., printed in *Proceedings* for February, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.

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points unexplained. On the face of the record there seems to be no good reason why the beam *D* should show a fiber stress 24% lower than the beam *B* which contains the greater proportion of sand, and hence, theoretically at least, should be the weaker of the two. The extremely low coefficient of elasticity of the beam *D*, as determined by the tests on the half length, is also unaccounted for.

Beam *A* is not reported, as to the full-length test, but the different values of the coefficient of elasticity for A_1 and A_2 might be accounted for by slight errors in reading the deflections. The figures for fiber stress show close coincidence. With the beam *B* there is a wide variation in the coefficient of elasticity determined from tests on the two ends. Why the elasticity of B_1 should be 100% greater than that for B_2, is not clear. Beams *C* and *D* in all cases show lower values for the elasticity for the second tests, while the fiber stress does not differ widely from the value obtained in the first test.

The coefficient of elasticity is computed properly for the elastic deformation only, since the inclusion of the total deformation in any case would give a false idea of the properties of the material. However, the amount of this total deformation is a matter that should be taken into consideration, practically, since a mass of concrete under stress changes its character, more or less, during the earlier stages of the loading, and subsequent tests may show materially different results from the initial. The intrinsic properties of the mass do not change, but there is, no doubt, a rearrangement of the molecules and a redistribution of the initial stresses, which are due to hardening, which may leave the mass more compact and solid, but, whether stronger or weaker than before, depends upon the care taken in fabrication and ramming in the moulds, as well as upon the percentage of water used and the conditions attending the process of hardening. It may be of interest to compare the results with those obtained from neat-cement mortars of other brands, and hence the following data are presented.

Table No. 2 gives a record of results obtained by the writer from flexural tests of a number of neat-cement mortar beams made to determine the ultimate fiber stress and the coefficient of elasticity. The beams were approximately 28 ins. in length, and 2 × 2¼ ins. in section. They were moulded in the spring of 1902 by Mr. H. B. Stevens, a student in the College of Civil Engineering of Cornell University, and were used in determining the time of initial and final set of mortar. Briquettes of the same mortar were made in order to test the effect of varying proportions of water on the tensile strength; but Mr. Stevens' investigations did not warrant any general conclusion. The beams, therefore, when tested, were about one year old, and had been kept, after hardening in air, in the College laboratory, at a temperature of about 65° Fahr. Four of the beams were of Cayuga Lake Cement, a brand manufactured near Ithaca, N. Y., and only quite recently placed

Mr. McCaustland. on the market. The other three bars were of the well-known Empire Portland brand.

The span was uniformly 24 ins., and the load was applied at the center by increments of 20 lbs. Deflections were measured by a micrometer screw, reading to ten-thousandths of an inch. Readings were taken for the permanent deflections of the bars, after the application and subsequent removal of each successive load.

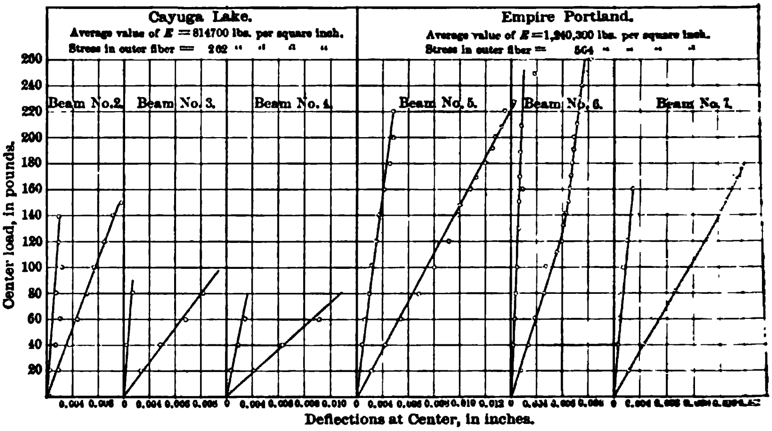

Fig. 2.

The diagrams on Fig. 2 show, as in Mr. Falk's experiments, the curves of permanent and elastic deflection; the intercept between these two curves at any load is the value taken for the deflection from which to compute the coefficient of elasticity. On Beams 2, 3 and 4 the value of *E*, the elasticity, was computed for central loads of 80 lbs., while for Beams 5, 6 and 7 the central load was 120 lbs.

TABLE No. 2.

Span=24 ins. Load at center. Age of beams=1 year.

No.	Brand.	Percentage of water in mixture.	Time of Set, in Minutes.		Section of Beam, in Inches.		Coefficient of elasticity, in pounds per square inch.	Extreme fiber stress in pounds per square inch.
			Initial.	Final.	Width.	Depth.		
1	Cayuga Lake.	23	130	230	2	2.75	....	571
2	" "	24	180	230	2	2.75	1 384 000	357
3	" "	25	160	235	2	2.75	600 000	238
4	" "	26	175	300	2	2.75	460 000	190
5	Empire Portland.	20	120	250	1.94	2.62	1 219 000	623
6	" "	30	235	360	2	2.75	1 582 000	618
7	" "	31.8	190	305	2	2.75	920 000	452

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It is quite noticeable that the values of the coefficient of elasticity and the extreme fiber stress for the Empire Portland beams range fairly close to those recorded by Mr. Falk, although these are of neat-cement mortar instead of a mixture of 1:2 or 1:3. It is possible, but scarcely probable, that a greater age in these beams would have developed a greater strength and a greater degree of stiffness, with a consequent rise in the value of E.

It is submitted, however, that these tests, like many others reported in various papers, are altogether too few to warrant definite conclusions. The percentage of water used and the extreme fiber stress seem to vary inversely, but this is by no means an established relation, except possibly for certain extremes. There is here a field for a very definite and extended series of experiments with standard American brands of cement.

In addition to the preceding—not in the form of a discussion, but as new matter more or less related—the results of certain tests on concrete and mortar columns are here presented.

These columns were constructed by the writer in February and March, 1900, in the laboratories of the College of Civil Engineering at Cornell University, where they were tested, under the direction of Professor C. L. Crandall, M. Am. Soc. C. E., with Mr. O. A. Johannsen, Instructor in Civil Engineering, in direct charge of the work.

The cement used was Alpha brand, taken from a fresh supply provided for use in the cement laboratory work of the college. The usual tests did not show any abnormal qualities. The sand was a clean, fine, and not especially sharp, bank sand from Fall Creek. A careful test of the sand grains determined that the size of 60% of the total weight was less than 0.081 in., while 10% was less than 0.044 in. Adopting Hazen's method of recording sizes of filtering sands, the uniformity coefficient is 1.84. The stone used was sandstone, varying in size from ½ in. to 2 ins.

The columns were circular, 10 ins. in diameter and 40 ins. long, constructed in wooden forms made of narrow staves held together by yokes, which served the purpose of hoops. The cement and sand were mixed dry and the stone added. The least possible quantity of water was used, so that when the forms were rammed full, very little moisture appeared on the surface, and there was no quaking of the mass. The forms were removed after 24 hours, and the columns remained in the basement of the College building until tested.

The temperature of this basement did not vary at any time widely from 65° Fahr. The columns were watered at intervals of about four days until three months old, after which no water was applied. The tests were made on a Riehlé 400 000-lb. machine, and shortenings were read from micrometer rods placed between yokes held to the column by

Mr. McCaustland. set-screws. Two rods, on opposite sides of the column, were provided, and contact was determined by an electric bell. At times the micrometers read widely different on opposite sides of a column, probably due to local weaknesses, but in all cases the mean of the readings was taken from which to determine the amount of shortening. The initial load was taken throughout as 1 000 lbs., which gave a unit stress of 12½ lbs. per square inch. On all columns, except Nos. 2, 4 and 5, the loadings were repeated five times before advancing to higher values, the micrometers being read at each application and release.

The diagrams on Fig. 3 show the stress and strain curves under the first loadings and also after a repetition of the loads, together with the permanent-set curves for the same conditions. The coefficient of elasticity is computed for the elastic deformation at 500 lbs. per square inch, except for the three mortar columns, Nos. 17, 18 and 19, which are computed at a load of 1 000 lbs. per square inch. The reason for the abnormal set shown in Column No. 3, with the accompanying high coefficient of elasticity, is not clear, and the mean value of E for the 1:2:3 mixtures is determined by using the values derived for Columns Nos. 1, 2 and 4 only. The 1:3:4 group gives fairly uniform results. The 1:3:5 mixture gives less uniform results, but is still within reasonable limits.

Owing to the slipping of the micrometers on Column No. 10, the stress and strain diagram for this specimen could not be plotted. This was true, also, of Column No. 16, of the 1:2:5 group. Column No. 13 gives an unusually low, as No. 14 gives a high, value of E, but these wide ranges of value are almost certain to develop in tests upon low concrete specimens in which the aggregate bears such a large proportion to the total volume. Where the matrix (cement and sand mortar) is but slightly in excess of the volume of voids in the aggregate, it is almost impossible to get a homogeneous mixture and to preserve the homogeneity of the mass while it is being placed in position and rammed. Segregation is bound to occur, with resulting abnormal qualities, as made evident by many tests.

The low unit stresses developed by the 6-in. cubes are no doubt due to the difficulty in moulding such a small block of fairly representative material. The writer believes that concrete cubes for crushing tests should never be less than 8 ins. on edge, and, preferably, 12 ins. There is a wide difference between the results obtained from crushing tests on 12-in. and on 6-in. cubes made from the same batch of concrete. Any form of test, on a concrete specimen, loses in value, unless the specimen can be assumed, without question, to be fairly representative in character. Hence, two general principles should govern in the preparation of the material for testing:

First.—Acquire and place on record a complete and comprehensive knowledge of every item which might determine or affect the physical

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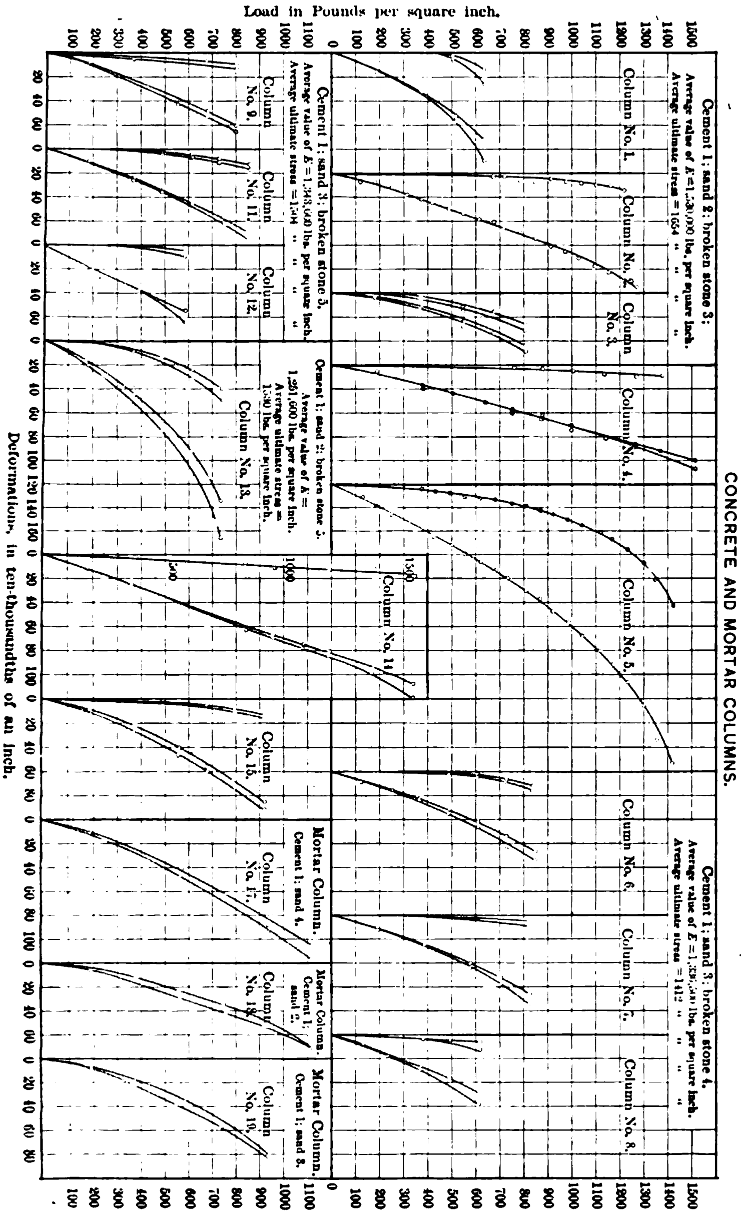

FIG. 8.

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or mechanical properties of the specimen. Character, composition, quality and form, as well as proportions and methods of fabrication, should form an important part of the history of a test specimen.

Second.—Keep in mind the practical limitations of commercial use, and avoid, if possible, the wide gaps which too often exist between laboratory results and those which may reasonably be expected in the field of "first-class work."

TABLE No. 3.

Proportions.	No.	Age at test, in months.	Load at failure, in pounds.	Area, in square inches.	Ultimate unit stress, in pounds per square inch.	Coefficient of elasticity, at 500 lbs. per square inch.	Average unit stress on 6-in. cubes of the same material.
Cement 1, sand 2 and broken stone 3.	1	14	79 300	79.3	1 000	1 050 000	1 751
	2	11	143 000	81.7	1 752	1 530 000	
	3	13	98 300	80.8	1 215	3 060 000	
	4	14	212 000	79.3	2 650	2 010 000	
Cement 1, sand 3 and broken stone 4.	5	10	120 000	80.8	1 484	1 100 000	1 [illegible]
	6	11	114 000	82.5	1 382	1 380 000	
	7	14	98 000	79.3	1 230	1 425 000	
	8	11	126 600	81.5	1 550	1 441 000	
Cement 1, sand 3 and broken stone 5.	9	14	126 400	81.5	1 550	1 450 000	1 092
	10	14	120 000	80.0	1 500	Not determined...	
	11	14	146 400	81.5	1 792	1 531 000	
	12	14	90 000	76.8	1 170	1 050 000	
Cement 1, sand 2 and broken stone 5.	13	15	85 000	81.5	1 045	840 000	1 [illegible]
	14	15	180 000	83.5	1 955	1 510 000	
	15	14	118 300	81.8	1 450	1 372 500	
	16	23	137 000	81.0	1 680	Not determined.	
Cement 1, sand 4.	17	23	215 000	81.0	2 660	2 775 000	
Cement 1, sand 2.	18	23	278 230	81.0	3 410	4 625 000	2 [illegible] 1 [illegible]
Cement 1, sand 3.	19	23	180 000	81.0	2 250	3 700 000	

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PAPERS AND DISCUSSIONS.

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THE PANAMA CANAL.

Discussion.*

By Messrs. W. E. Crane, Boyd Ehle, William H. Burr and George S. Morison.

W. E. **Crane**, Jun. Am. Soc. C. E.—That part of the discussion relating to the Pacific terminal of the canal has interested the speaker very much, and he would like to suggest to the author that it should be discussed further. Mr. Crane.

The length of the canal is approximately 43 to 45 miles, and the coastal plain on the Pacific Coast is about 6 miles in width. It may be assumed that the distance thus taken is measured from mean high water on the Pacific Coast to mean high water on the Atlantic Coast. The City of Panama is situated on a point, and its elevation is but a few feet above the Pacific Ocean. At extreme low tides, there is exposed a mud flat extending into the ocean 3 to 5 miles, possibly a greater distance. Coast line vessels anchor near the three islands which are from 4 to 5 miles from the Panama dock. The terminal of the canal is about 2 miles along the shore above Panama.

The speaker visited this section of country in 1896, and remembers a discussion, on the day he was at this terminal, relating to the direction and distance from the shore line to deep water, the width and depth of excavation, and the method proposed for protecting the banks, the probable cost of this section, what action the winds and waves would have on the banks of the canal, and how much dredging would be required annually in this section of the canal.

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* Continued from March, 1903, *Proceedings*. See January, 1903, *Proceedings*, for paper on this subject by George S. Morison, Past-President, Am. Soc. C. E.

Mr. Crane. Mr. Harrison has mentioned this portion of the canal, but only as to the depth advisable to permit vessels (especially war ships) to enter the canal at extreme low tide.

A further discussion of the Pacific terminal, by members who understand the conditions and have had access to the plans and estimates, would be very interesting and beneficial.

Mr. Ehle. BOYD EHLE, Assoc. M. Am. Soc. C. E.—As usual, Mr. Morison, in his statement of facts, has left little to be said. In the discussion, however, certain statements have been made which do not agree with the speaker's knowledge of actual conditions observed on the Isthmus at various times in years of service on the surveys and canal work.

The Chagres is not subject to great scouring action, and there cannot be many of the dangers predicted regarding the silting up of the channel. Above Alhajuela the Chagres is simply a mountain stream, running part of the way through rocky gorges. The soil is not a lava ash, as has been assumed, but is a clay held in place by the rank vegetation of the tropics. Below Alhajuela and nearer to the canal location there is some alluvial soil, but of no great extent, and this, in the case of a lock canal, would form part of a lake bottom, and would not be affected by the slight current to which, in Lake Bohio, even the great floods will be reduced.

Although the lock plan provides a certain solution of the flood problem, by the use of the Gigante Weir, the question is often asked, "Why not divert the Chagres to the oceans"? This was examined closely enough by the Panama Canal Company to show that there were no evident possibilities in that line. Surveys were made to find the shortest tunnel line possible, but the results gave no hope of anything feasible and economical, and the idea was abandoned.

The Tiger Hill cut-off undoubtedly has some merits not possessed by the river line, and these, as stated by Mr. Morison in a preliminary way, will lead probably to its thorough examination in the future. It could not be incorporated in the careful and conservative report of the Isthmian Canal Commission, it is said, on account of the lack of data. This will not be against it in a future study, and its merits and disadvantages will no doubt be weighed properly by the Commission before actual construction is started.

The solution of the canal problem by the construction of a sea-level canal has never appeared to the speaker as an engineering solution, as engineering is usually defined. There have never appeared to be any compensating advantages for such an excessive extra expenditure of money and time, and none appears to have been stated clearly and sustained.

Nature, through the tides, makes one lock necessary, and that, during most of the time, is the check on the canal's usefulness, as surely as more locks, provided they are in good order. The time gained in doing away with the locks is insignificant in comparison with that required for the long journey around The Horn which the lock canal will save. It cannot have any recognizable value, as far as can be seen in the future. When it has such a value, probably canals will not be necessary, and the air, instead of the water, will be the highway of communication. It is true that locks are likely to be deranged, but should not, as an engineer's work, be likely to fail; besides, as a precautionary measure, the plans of the Commission provide for twin locks. Mr. Ehle.

The question of a sea-level canal is not an imminent one, as it is perfectly feasible to cut a lock canal to a sea-level canal at any time in the future, if so desired; and it can be safely left to the engineers of the future to decide whether a sea-level canal is required.

It seems that all the schemes for the control of the Chagres in relation to a sea-level canal were never worked out in detail. There was much procrastination on this problem by the French Company, and their tardy plan, after the failure of the first company, has never received any very enthusiastic encomiums from the engineers who have reviewed it.

A sea-level canal would be exposed to all the troubles produced by the great floods of the Chagres, with little chance for any protection. One scheme for the control of floods, however, would be the Tiger Hill location, which would take the canal out of the lowest part of the valley and into a safe position from Bohio to Colon.

The decrease in the height of the locks would seem to be desirable if contrasted with the loss of time incident to the operation of an extra lock, as a proper measure of conservatism, provided no serious difficulties were encountered in its construction.

Another point is that of decreasing the cost on the Pacific side by taking advantage of the rise of the tide. This would seem to be a proper utilization of Nature's forces—as much so as a switch-back over a mountain before a railway is built through it. Why not try it? A few hours of time are nothing compared with the days of steaming by the *Oregon*. When the demand becomes imperative, and the few hours saved would mean a proper return on the outlay, then build it as deep as such value will justify.

As to the case of a fleet, in the rare case of war, being at a disadvantage if divided by the fall of the tide, it appears that the enemy would be in as great trouble; however, that is a very remote contingency.

William H. Burr, M. Am. Soc. C. E.—In this paper Mr. Morison has, among other things, set forth in deserving prominence some of the salient features of the Isthmian Canal Company's plan for the Panama Canal and his proposed modifications of them, which latter were also mostly, if not entirely, fully considered by the Isthmian Canal Commis- Mr. Burr.

Mr. Burr. sion. There is obviously a little delicacy in entering into the discussions in much detail which took place in the Commission regarding these or other matters, and it is the speaker's purpose to consider, as any member of the Society may, only the salient engineering features of the matter. It may be said with propriety that the shortened line between Bohio and Colon was considered carefully by the Commission, but only a limited examination was given to it in the field. This line is an old one, and was probably first proposed by Commander E. P. Lull, U. S. N. It possesses undoubted merits, and is worthy of careful consideration before final construction is undertaken, but in discussing this feature at this time two things are to be carefully borne in mind; the first is the incompleteness of the actual examinations made on this shortened route, and the second is the fact that a large amount of work has already been done on the French line between Bohio and Colon. It is hazardous to make an exact prediction of cost in the absence of necessary information on which to base it. Apparently, a comparatively small amount of money might possibly be saved by adopting the Lull line, but that cannot be stated confidently in the absence of complete borings and other requisite examinations. A serious, but not insuperable, objection is the considerable amount of embankment necessary between Bohio and Tiger Hill. These embankments may reach the height of 25 ft., and possibly a little more. While such embankments may be made safe, and are entirely justifiable under conditions such as those existing in connection with the Nicaragua route, they certainly are not desirable, and they should be avoided unless necessity exists for them, or adequate compensating advantages are attained.

Again, the adoption of this shortened line and the Tiger Hill locks involves the loss of time by a vessel traversing the canal necessary to make the additional lockage. As the gain in distance is only about 1¼ miles, the increased time required to pass the lock would be far more than that necessary to make the added distance by the French line. The introduction of the additional lockage, therefore, would be a sensible loss of time in passing through the canal, in fact, so great a loss of time as to increase materially the time of passage over that required by the adopted line. In other words, for the purposes of navigation, the canal would actually be lengthened by the Tiger Hill line and lock. The additional lock would also increase the opportunities of accident at the lock gates, with the added chance of destruction of the short Tiger Hill level by an accident at the Bohio gates suddenly releasing the lower-lock volume of water.

If the work of constructing the canal were to be begun as an entirely new project, it is not unlikely that the shortened line between Colon and Bohio without a lock might be preferable to that on which so much has now been completed. With the conditions actually existing, however, it is the speaker's judgment that complete examinations along the shortened or Lull line would show little or no difference in cost of completion. Mr. Burr.

It is true, as Mr. Morison states, that the locks planned by the Isthmian Canal Commission are larger than those which have ordinarily been constructed, and yet such locks as those built at Sault Ste. Marie save the construction of the Isthmian Canal locks from being violent departures from precedent, even with their material increase of lift. The massive masonry construction and other large features of these proposed locks would probably frighten few civil engineers, nor do they involve sufficiently difficult operations either of design or construction to make it necessary to incur the construction of extensive embankments to avoid them. It is not unlikely that many, if not most, engineers would prefer to avoid the embankments by resorting to locks of high lift.

It has been shown, in the discussion of a proposed plan for the Bohio Dam by Mr. Morison, that the consideration of seepage involves about as great uncertainties as can ordinarily be attached to engineering speculation, and, indeed, that no quantitative results can be predicted confidently in regard to it. Hence it is scarcely required to give detailed consideration to such a feature of the work. It may be stated, however, that it is not quite clear how the seepage under a dam at Bohio placed on porous material would be affected by the proposed Tiger Hill level. The total head between the surface of the water in Lake Bohio and that in the river-bed below the dam, or dam and canal, would remain unchanged, and as the seepage through such open and porous material would depend upon that head it could be modified only by the slightly lengthened seepage channel. The amount of seepage, therefore, cannot reasonably be supposed to be changed sensibly by this feature. Some recent experiences of the speaker, in connection with the seepage or flow of water through fine sand, or fine sand and silt, have impressed him in a marked manner with the danger attending the construction of a dam built on porous material, which he pointed out in his discussion on Mr. Morison's paper on "The Bohio Dam."

There are two other features of the modified canal plan brought out by Mr. Morison which may be treated largely as one, namely, decreasing the depth of excavation in the Culebra Cut by 3 ft. and the depth of excavation in the entrance channel of Panama Bay by 10 ft. The proposition to raise the bottom of the excavation in Culebra Cut 3 ft. to Elevation + 50, instead of retaining it at Elevation + 47, recommended by the Commission, would trench seriously upon the capacity of the canal for ships of the greatest draft. Obviously, it must be recognized that by far the great majority of ships passing through the canal will have considerably less than the maximum draft.

Mr. Burr. At the same time it is also to be remembered that the purpose of this canal construction, as expressed in the language of the law on which the instructions to the Commission were based, is to afford accommodation for the greatest ships afloat. It is only reasonable to suppose that this expression meant complete accommodation and not partial accommodation during some seasons of the year or stages of the tide. This restriction in the canal would lead to seasonal restriction of navigation capacity, which, however, might be partially compensated or relieved by the construction of the Alhajuela Reservoir.

The decrease of depth of 10 ft. in the Panama Channel would be a daily restriction of navigation capacity, since the throttling effect of the diminished channel depth would occur at every tide. For one-fourth of the entire time the canal would be shorn of its greatest capacity. Even if it be admitted that the maximum delay of any ship would not be more than 6 hours, there are conditions under which that might be serious. This consideration carries with it greater gravity in that it would affect the largest ships.

These features were considered most carefully by the Commission, but it seems to the speaker that the decision to plan a canal possessing the maximum prescribed capacity was wise and should not be departed from. If the United States Government is to complete a great canal across the Isthmus for the purpose of affording the freest waterway for ships, the accommodations provided should be subject to no throttling or other substantial restriction of a diminished canal depth at its central portion or at either extremity. Such material disadvantages would constitute objections so serious that the demand to relieve them would probably follow closely the opening of the canal.

The practicability of a sea-level canal across the Isthmus of Panama is much more real than has ordinarily been considered, as Mr. Morison shows, and as indicated so clearly in the report of the Isthmian Canal Commission. In the event of such a construction it would undoubtedly be wise to make the canal prism of such area of section as to receive the flood waters of the Chagres modified by the storage resulting from the construction of the Alhajuela Dam. The question of the area of the prism is in reality the greatest single question involved in the sea-level plan, and whether an area of section of even 15 000 sq. ft., mentioned by Mr. Morison, would be sufficient is not yet determined. Further, it is a serious question whether, even with an additional expenditure of $125 000 000 or more, and the greatly extended time required for construction, it would not be the part of real wisdom for the United States Government to undertake at once the sea-level plan, rather than the elevated plan, with its advantages of reduced cost and shortened time.

Mr. Morison. GEORGE S. MORISON, Past-President, Am. Soc. C. E. (by letter).—The question of lift of locks is one on which the writer feels more

Mr. Morison. doubt than he does about any other point. The addition of the third lock means more gates and more possible risks; it increases the time of passage by the time necessary to pass through the additional lock. The additional risk is not serious, since the destruction of a gate in the Tiger Hill lock would not affect the water in the summit level, and the gate could readily be replaced. Furthermore, by keeping the lifts of the locks practically uniform throughout, the number of spare gates which must be kept on hand for repairs and renewments, would be reduced. The time required by the extra lock does not appear to be of material importance. The time required to pass through the canal will be a matter of convenience of meeting points more than of close calculations of speed. As many vessels as possible will meet in Lake Bohio, and under any plan it will take longer to pass from Panama Bay to Lake Bohio than from Colon Harbor to Lake Bohio.

The total distance from the shore end of the enlargement for Colon Harbor to the shore end of the wide channel through the mud flats in Panama Bay is 41 or 42 miles. This is divided into two canals by a lake more than 12 miles long in the middle; 13 or 14 miles of canal navigation, not including locks, lie between Colon Harbor and the lake; a little more than 14 miles of canal navigation, not including locks, lie between Panama Bay and the lake. It is the navigation of these two canal sections which will regulate the passage across the Isthmus. While the speed of steamers through the canal will vary with their size, the time which a ship of mean dimensions would take to pass through these two sections may be estimated as follows, the speed in the canal being taken at five miles per hour:

Colon Harbor to Tiger Hill lock, 7.28 miles..	1 hour	27 minutes
Tiger Hill lock..........................		45 "
Tiger Hill lock to Bohio locks, 5.73 miles...	1 "	9 "
Bohio double locks......................	1 "	15 "
	4 hours	36 minutes

Panama Bay to Miraflores lock, 4.15 miles..		50 minutes
Miraflores lock..........................		45 "
Miraflores lock to Pedro Miguel locks, 1.34 miles		16 "
Pedro Miguel double locks................	1 hour	15 "
Pedro Miguel locks to Lake Bohio, 8.84 miles.	1 "	46 "
	4 hours	52 minutes

This time could be reduced for smaller vessels; it will be exceeded by the largest vessels. It may be said, in a general way, that the time required to pass from either ocean into the interior lake will not be less than four hours, and it should not exceed five hours, except

Mr. Morison. for the very largest class of ships. To these figures should be added the time required to pass through the lake and the time lost in Colon Harbor or Panama Bay. It would, perhaps, be fair to add an hour for each of these terminals, and 1½ hours for the passage of the lake; this would make the total time required for the passage of the canal from 10.5 to 12.5 hours.

Many steamers would take coal at Colon, and all would have to stop at the entrance port to pay tolls, take pilots, etc. There would be abundant room to tie up vessels in the broad harbor section at the Colon end. There is abundant anchorage in Panama Bay, the distance from the canal entrance to this anchorage being determined by the size of the ship and other considerations. There is ample room for ships to anchor in Lake Bohio, where they could get fresh water, and, if necessary, make slight repairs. It is not probable that either section of canal would be traversed by night, except by the smallest class of vessels and in emergencies. Ships would prefer to enter the canal from either end about daylight or soon after noon. Ships entering in the morning would make a daylight passage, meeting in Lake Bohio. Ships entering after noon would spend the night in Lake Bohio and pass out on the following morning, proceeding under despatch orders and meeting the inbound ships at the locks. The Tiger Hill lock will be approximately half way between Colon and Lake Bohio, and the Pedro Miguel locks are approached in about the same length of time from the lake and from Panama Bay.

The intermediate level would reduce the seepage head between the lake and the level below the dam one-third, and increase the distance through which seepage must pass between the lake and the lower level of the Chagres at least three times. The estimated seepage would therefore be reduced one-third. The writer, however, considers that this question of seepage was covered in the discussion of the previous paper,* and does not believe that this reduction would be of sufficient advantage to have any important bearing on the main question. The saving of distance by the use of the Tiger Hill line is also of little value, but the saving of curvature is more important. The great advantage of this location, however, is that it keeps away from the low valley of the Chagres at places where the exposure is greatest. A small map has been prepared showing in detail the present course of the Chagres, and the two swamps through which the overflow of the spillway must be taken if the old location is followed, and indicating the land which is less than 10 m., or 33 ft., above tide level.† Below the dam the Chagres no longer follows its old bed, but for five miles runs through the canal, its old crooked course having been silted up, and from this five miles it must be excluded if the French location is adopted. If the lower location is adopted a channel must be cut through the ridge between the two swamps, and the canal must be protected by levees for at least five miles. This is undoubtedly practicable and can be made safe, but safety is always a measure of degree. The levees built for this purpose, which would be exposed to the wash of a flooded river, would be a more serious matter than the risk to the small embankments required to sustain the canal on the Tiger Hill location. The latter embankments would be exposed to no such wash, and the spoil from the canal would be enough to make them several hundred feet thick. Furthermore, the indications are that it would cost less to build the Tiger Hill line at tide level to the Bohio Locks than to complete and protect a canal on the original location. The writer, however, favors the intermediate lock. Mr. Morison.

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* "The Bohio Dam." *Transactions*, Am. Soc. C. E., Vol. XLVIII, p. 235.

† This map not received in time for reproduction here; it will appear with this discussion when printed in Vol. L of *Transactions*.

The proposition to raise the bottom of the canal through the Culebra Cut 3 ft., as described in the paper, would not necessarily affect the use of the canal for ships of the greatest draft. The depth of 35 ft. was selected to allow ships drawing 32 ft. to pass easily through it. If the precedent of the Manchester Ship Canal is followed, ships drawing 32 ft. could always be handled, although it would be hard to steer them. The writer, however, did not propose to reduce the depth through this summit level, but suggested that there were other methods of maintaining it, besides increasing the depth of this cut. The cost of the Alhajuela Dam will differ but little from the cost of this 3-ft. additional excavation, and will provide a much greater supply of water. If the construction of this dam is postponed until the completion of the canal, the cost of building a railroad to the dam site will be saved, as it can then be reached by water, and other economies, which attend the postponement of work until the rush is over, can be realized. It is not improbable that all the necessary water can be stored by the use of flash-boards, one of the cheapest devices ever made.

The principal objections raised to reducing the depth on the Pacific level relate to military rather than commercial conditions. It must be remembered, however, that the largest merchantmen of to-day are twice as big as the largest naval vessels, and that there are practically no naval vessels which draw over 30 ft. Furthermore, no fleet consists entirely of the heaviest class of ships, but every fleet contains a number of comparatively light-draft boats, used for despatch service and other purposes. If we assume that an entire fleet is taken through the canal at once, a very improbable supposition, the heavy-draft fighting ships will either precede or follow the light-draft ships, according as they expect to encounter a hostile fleet in front of or behind them. It would take approximately an hour to pass from deep water in Panama Bay to the Miraflores Lock. Assuming six hours as the length of time from mean tide to mean tide, Mr. Morison. this would leave five hours for the passage of the locks, which, allowing half an hour for each passage, special preparations being made, and using both locks, would enable 20-ft. deep-draft fighting ships to pass from Panama Bay into the canal on a single tide. It is not probable that any such number of deep-draft ships will ever be concentrated in a single fleet.

It is the writer's opinion that the advantages offered by Lake Bohio as an interior lake which divides the transit into two short canals more than make up for the delays and limitations of the locks. The strongest argument in favor of the tide-level canal is the vulnerability of the locks. In time of war the canal might be closed entirely by a small guerrilla force. An accident, by which a heavy steamer carried away the gates of a lock, occurring near the beginning of the dry season, might lead to the depletion of water in the lake to such an extent that navigation by deep-draft vessels would be impeded for several months. No such accident could occur to the single tide lock required for the tide-level canal. The danger from malicious destruction may be neglected, as the same harm could be done in various ways, although not as easily, in a tide-level canal. The gate must be kept safe by constant care, and undoubtedly some device can be made by which the discharge through the locks, when the gates are broken, can be stopped. Although the writer would prefer a tide-level canal when completed, he believes that it would be a serious mistake to undertake the tide-level plan at once.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

THOMAS CURTIS CLARKE,* Past-President, Am. Soc. C. E.

DIED JUNE 15TH, 1901.

Thomas Curtis Clarke, the youngest son of Samuel Clarke, of Boston, Massachusetts, was born on September 5th, 1827, in Newton, Massachusetts. It is a tradition that his earliest known ancestor, Thomas Clarke, of Plymouth, came over in the *Mayflower*, as Mate. If so, he went back to England in that vessel, for he arrived the next year as passenger in the *Anne* and settled in Plymouth. He was a man of some note, and several of his personal belongings are to be seen among the relics preserved in Forefathers Hall in that town. Mr. Clarke's grandfather, Major Samuel Clarke, of Boston, married Martha, daughter of Obadiah and Martha Curtis, members of a prominent Boston family. Mr. Clarke's father was a man of varied talents, both scientific and artistic, and his mother was a daughter of General William Hull, of Revolutionary fame, and a first cousin of Commodore Isaac Hull, commander of the frigate *Constitution* (Old Ironsides) when she destroyed the English frigate *Guerriere*.

Mr. Clarke had four brothers and one sister, the best known of them being the Reverend James Freeman Clarke, a Unitarian preacher and author, named for his grandfather, the Reverend James Freeman, who married Martha (Curtis), the widow of Major Samuel Clarke. It was from such antecedents that Mr. Clarke inherited the literary and artistic tastes which characterized him, and which were second only to his engineering ability.

Mr. Clarke's early training was given by his grandmother, Mrs. Freeman, with whom he lived while a child. He says of her: "She taught me to read and to speak the truth." She may also have taught him his characteristic modesty and self-effacement. From 1841 to 1844 Mr. Clarke fitted for College at the Boston Latin School, under the famous Master, Francis Gardner. In the latter year he entered Harvard, and was graduated in the summer of 1848, on which occasion he officiated as class poet.

Mr. Clarke had intended to study the Law; but, being in delicate health at that time, he decided to adopt the profession of Civil Engineering. He obtained a position in the Engineering Corps of the Mobile and Ohio Railway, under Captain John Childe, the foremost railroad engineer of the day. Here he learned the practical work of railroad location, and here he remained until June, 1849, when a severe attack of fever compelled him to return to Boston. During that fall, while waiting for another position, he studied architecture, in the office of E. C. Cabot, of Boston, gaining knowledge of that profession, and of mechanical drawing, that was of service to him later. At that time there were no schools of engineering, and young engineers had to obtain their technical education as best they could.

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* Committee appointed by the Board of Direction to prepare this memoir: John F. O'Rourke, Adolphus Bonzano and Eliot C. Clarke.

Early in 1850 he secured a position as draughtsman under Mr. Shanly, Resident Engineer of the Ogdensburg and Lake Champlain Railway. When the work with which he was connected was completed, he returned to the Mobile and Ohio Railway, and took charge of one of the parties locating that road. This work lasted until September, 1851, when Mr. Clarke went to St. Louis and afterward to Chicago, in which city his mother and two of his brothers were then living. While in Chicago he studied in the office of Edward Burling, an eminent architect of that city. At this time, at the request of William B. Ogden, a public-spirited citizen, Mr. Clarke made a design for a tunnel under the Chicago River.

In October, 1852, he accepted a position under Mr. Benedict, Chief Engineer of the Great Western Railway of Canada, as Resident Engineer of the Second Division, which extended from St. Catherines to Dundas and included much heavy work and the shops at Hamilton. His assistants were Amory Dexter, of Boston; Thomas Ridout, of Toronto, and Augustus Bacon, from the Ogdensburg and Lake Champlain Railway. It was here that Mr. Clarke gained his first experience in foundation work in which he was so successful afterward. After the completion and opening of the road, in 1853, Mr. Clarke went to Port Hope, Ontario, Canada, as Assistant Engineer, under Mr. Benedict, of the Port Hope and Peterboro Railway. This road was finished in 1856, when Mr. Clarke and Mr. George Tate, one of the engineers of the Grand Trunk Railway, took a lease of it and operated it as a private enterprise. In 1858 the directors of the railway broke their contract and took the road from Messrs. Clarke and Tate, who recovered damages after a suit lasting about a year.

In November, 1858, Mr. Clarke was put in charge of one of the three divisions of the Government Survey of the Ottawa River, his work covering French River, Lake Nipissing and the Mattawan. His experiences in the field during the severe Canadian winter were most interesting, and his work was done so well and so promptly that he was placed in charge of the entire survey. The thoroughness of his work is shown by the fact that twenty-five years later, when the Canadian Government improved the Ottawa River, they adopted Mr. Clarke's plans and his exact location for a lock and dams at Carillon, at the head of the Lake of Two Mountains.

In the fall of 1869, Mr. Clarke, in partnership with Ralph Jones and Edward Haycock, took a contract for building the two Government Departmental buildings at Ottawa. Among other materials needed were iron beams, and to purchase these Mr. Clarke visited England in March, 1860. There he made the acquaintance of many distinguished men; among others, William Fairbairn. He was abroad about two months, returning to Quebec on an Allan Line steamship. Sir Hugh Allan had been urged to start his ships from Galway instead of Mobile, in North Ireland, and he sent one of them to try the harbor. It was on her that Mr. Clarke sailed, and he thus was one of the few who ever sailed from that port, as the one trip demonstrated its unsuitableness. The Ottawa buildings were finished in 1866.

About the end of the same year Mr. Clarke was engaged to build a bridge over the Mississippi River at Quincy, Illinois, for the Chicago, Burlington and Quincy Railway. This was the first iron bridge built across that river, and the securing of stable foundations presented many difficulties. The entire bridge was completed in two years without employing any contractors except for furnishing the iron superstructure. This was removed later and a heavier one substituted, on account of the great increase in modern trainloads; but no change was needed in the old piers.

In the fall of 1868 Mr. Clarke moved to New York City, where he formed a partnership with Charles Kellogg for furnishing and building iron structures, under the name of the Phœnix Bridge Company. In the spring of 1870 he moved to Philadelphia, and formed a new firm under the name of Clarke, Reeves and Company. Mr. Clarke was the senior partner, and his associates were Samuel Reeves, John Griffen and Adolphus Bonzano, of Phœnixville, Pennsylvania. The firm of Clarke, Reeves and Company was one of the leading bridge builders of the United States, and, among other works, constructed the Girard Avenue Bridge, over the Schuylkill at Philadelphia, many railroad bridges in the United States and in Canada, the Kinzua Viaduct on the Erie Railway, and a large part of the Elevated Railway system in New York City.

Mr. Clarke severed his connection with this concern in 1883, and in the next year became one of the original members of the Union Bridge Company, with offices in New York. During his connection with this concern, it built the Hawksbury Bridge in Australia, (the contract for it being taken in competition with the whole world), and the Poughkeepsie Bridge over the Hudson River. In building both these bridges the foundation work was very difficult, and Mr. Clarke's great experience in such matters stood him in good stead.

Mr. Clarke retired from the Union Bridge Company late in 1887, and during the remainder of his life carried on a business as Consulting Engineer. He also traveled much, and was prominent among the members of this Society when they visited Europe in 1889. He was consulted by Henry M. Whitney, of Boston, in regard to the elevated railways in that city, and also in connection with mining development work in Nova Scotia. He was Consulting Engineer for the City of New York in building the Third Avenue and the Willis Avenue Bridges, being responsible for the design and construction of them. These were his last works, and he died on June 15th, 1901, in New York City, after a brief illness.

Mr. Clarke was elected a Member of the American Society of Civil Engineers on March 18th, 1868, and a Fellow on May 20th, 1872. He served as a member of the Board of Direction for the year beginning November, 1878, and as Vice-President from November 2d, 1870, to November 1st, 1871. From January 15th, 1896, to January 20th, 1897, Mr. Clarke was President of the Society. He was a Member of the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and of the American Philosophical Society of Philadelphia. He was one of the first of the American members of the British Institution of Civil Engineers, and the only American engineer who ever received both the Telford Medal and Premium, they being awarded to him for a paper, written in 1878, on "The Design Generally of Iron Bridges of very Large Span for Railway Traffic."

Notwithstanding his modesty and retiring disposition, Mr. Clarke was very popular. He was a member of many clubs and associations in different parts of the country, and in New York City was a member of the Union, Century, Harvard, Manhattan, St. Andrew's Golf and other clubs. He contributed many professional papers to the various engineering societies to which he belonged. He wrote the article on "Engineering" for "The Progress of the Century," published in 1900, to which men eminent in other branches of knowledge also contributed articles.

In the *Minutes of Proceedings* of the British Institution of Civil Engineers, Sir Benjamin Baker writes thus:

> "The death of my old friend Mr. Clarke will be sincerely lamented by many British engineers, for no one has done more than he to promote the cordial brotherly relationship which now happily exists between American and British engineers. It also severs one more link with the past, for Mr. Clarke's early experience with bridge building was in the days when there was hardly one point of resemblance between American and British wrought-iron bridges, the former being modeled after the type of the original timber-truss construction and the latter on that of the cast-iron shallow-girder system. Mr. Clarke sometimes said that he shuddered when he thought of some of his early bridges, with long, slender cast-iron posts, slight lateral bracing, and totally inadequate pin-connections, even the floor girders being of the latter type, instead of the heavily-riveted low-stressed type which he lived to see substituted in all American bridge-work, as he

also saw each country gradually introduce the good points of the other's practice, so that no vital difference now distinguishes European and American bridges."

Mr. Clarke's life and works illustrate the highest form of engineering ability, while his modesty and straightforward, lovable character won for him hosts of friends. His death removed one of the brilliant lights of the engineering profession.

WILLIAM DURFEE GELETTE, M. Am. Soc. C. E.*

DIED APRIL 27TH, 1902.

William Durfee Gelette was born in Fairhaven, Massachusetts, on March 1st, 1847, and received his education at the Massachusetts Institute of Technology, being a member of the Class of 1869.

After leaving college he was employed until 1875 on various engineering works in New England, including water supply, drainage, iron bridge construction and street improvements, under such masters as Clemens Herschel and J. Herbert Shedd.

In 1875 Mr. Gelette went to California and entered the employ of the Southern Pacific Railroad Company, with which company and its successors he remained, almost continuously, up to the time of his death. He was in charge of the construction of the Southern Pacific transcontinental line from the Colorado River, on the border of California, to the Pecos River, in Texas, a distance of nearly 1 000 miles. Later, he was in charge of the construction of many other lines for that company, and from 1883 to the time of his death he occupied the second place in the Engineering Department of the road.

Mr. Gelette's life was ideal from the standpoint of an Engineer: Conscientious, hard working, tireless, he took up everything presented to him with the thorough method necessary to achieve the best results. These qualities made him the trusted lieutenant of those he served, and, combined with his sympathy and patience, earned for him the highest regard of his subordinates.

He was married in Boston in 1871, and his married life was a particularly happy one. His nature was domestic, and he enjoyed nothing more than his home and his family. His widow, a son and a daughter survive him.

In the early part of April, 1902, in the interests of his employers, he visited El Paso, Texas, and was taken ill. His conscientious regard for his work kept him at his post until it was complete, after which his strength barely permitted him to make the return trip to his home, in Oakland, California, where he quietly passed away a few days later.

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* Memoir prepared by W. B. Storey, M. Am. Soc. C. E.

He was elected a Member of the American Society of Civil Engineers on April 1st, 1885, and always took the greatest interest in its work.

JOSEPH MILLER WILSON,* M. Am. Soc. C. E.

DIED NOVEMBER 24TH, 1902.

Joseph Miller Wilson was born at Phœnixville, Chester County, Pennsylvania, on June 20th, 1838. He was a son of William Hasell and Jane Miller Wilson. His father and his grandfather were well-known civil engineers in the United States, his father being an Honorary Member of the American Society of Civil Engineers, and for many years Chief Engineer of the Pennsylvania Railroad. Mr. Wilson's great-grandfather and great-great-grandfather were among the most prominent civil engineers of their time in Scotland.

After a thorough preparation in private schools, Mr. Wilson entered the Rensselaer Polytechnic Institute, of Troy, New York, and was graduated therefrom in 1858, with the degree of Civil Engineer; after which he took a two years' special course in analytical chemistry with Professor F. A. Genth, of Philadelphia.

In 1860 Mr. Wilson entered the service of the Pennsylvania Railroad as Assistant Engineer, and in 1863 became Resident Engineer of the Middle Division. In 1865 he became Principal Assistant Engineer, and, later, Engineer of Bridges and Buildings of the Pennsylvania Railroad, continuing in the service of this road until January 1st, 1886.

Among the various structures designed and built by Mr. Wilson during this period were the Susquehanna and Schuykill Bridges, the original Broad Street Station, the Baltimore and Potomac Station at Washington, the Main Exhibition Building and Machinery Hall of the Centennial Exhibition, and, later, the Drexel Building and the Drexel Institute.

In 1876 Mr. Wilson, with his brothers, organized the firm of Wilson Brothers and Company, Civil Engineers and Architects, and this firm has done a very large amount of detail and expert work. The bridges designed and erected by him comprise all those on the Pennsylvania Railroad for many years, and many on other roads, the number too great to mention in detail. His firm were engineers and architects for numerous stations, shops, etc., on various railroads: Shops of the Northern Central Railroad at Baltimore; the Alleghany Valley Railroad shops at Verona, Pennsylvania; stations and shops for the Ninth and Third Avenue lines of the New York Elevated Railroad; stations and shops for the New York, West Shore and Buffalo Railroad; and stations on the Lehigh Valley, New Jersey Central, and Philadelphia and Reading Railroads.

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* Memoir prepared by Joseph M. Knap, M. Am. Soc. C. E.

Mr. Wilson was Chairman of the Board of Expert Engineers on the Washington Aqueduct Tunnel and Reservoir, acting under a joint Commission of Congress, in 1888-89; was Chairman of the Board of Expert Engineers to examine and report on the railroad terminal and station question at Providence, Rhode Island, in 1888; was one of the expert engineers to make examinations and report on the condition of the elevated railroads in New York City. He was one of the experts on the designs for the approaches of the New York and Brooklyn Suspension Bridge, and also one of the expert engineers reporting to the Board of Rapid Transit Commissioners for the City of New York, in 1891. In more recent years he was the Consulting Engineer for the Philadelphia and Reading Railway Company, and had charge, for that company, of all work on the Pennsylvania Avenue Subway, in the City of Philadelphia. He was one of the engineers appointed to examine and report on the improvement of the water supply for the City of Philadelphia, in 1899, the work being now carried out in accordance with that report.

Mr. Wilson wrote many scientific and engineering papers, among them the "Mechanical," the "Scientific," and the "Historical" for the "Illustrated Catalogue of the International Exhibition of 1876." He also wrote historical papers on this exhibition for London *Engineering*. By special request, he wrote a paper, on "American Permanent Way," for the British Association. He also wrote a comprehensive paper,* "On Specifications for Strength of Iron Bridges," and a paper † entitled "The Philadelphia and Reading Terminal Railroad and Station in Philadelphia," for the American Society of Civil Engineers; a paper on Port Perry Bridge, for the Institution of Civil Engineers; and a paper ‡ on "Schools," with particular reference to Trade Schools, especially those of France and England. He also wrote sundry papers for various scientific and engineering journals.

As an inventor, Mr. Wilson took out several patents: On bridge details, flushing tanks for sanitary purposes, etc., etc.

He held many positions of honor and responsibility, some of them being as follows: Member of the American Society of Civil Engineers; Member of the Institution of Civil Engineers; Fellow of the American Institute of Architects; Member of the Franklin Institute, of which he was Manager from 1868 to 1887, and President for ten years, 1887 to 1897; President of the Engineers' Club of Philadelphia for 1888; Member of the American Philosophical Society; Fellow of the American Association for the Advancement of Science; Member of the Century Association of New York City.

Mr. Wilson received the honorary degree of Master of Arts from the University of Pennsylvania in 1877. At the Centennial Exhibition of 1876, in Philadelphia, he received medals and awards for designs of bridges and buildings, and in 1878 he received the Telford Premium from the Institution of Civil Engineers.

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* *Transactions*, Am. Soc. C. E., Vol. XV, pp. 389, 484; Vol. XVI, p. 38.

† *Transactions*, Am. Soc. C. E., Vol. XXXIV, p. 115.

‡ *Journal*, Franklin Institute, 1889–90.

He was married to Miss Sarah Pettit, daughter of Judge Thomas McKean Pettit, on May 24th, 1869. They had two children, Alice May and Mary Hasell Wilson.

Mr. Wilson died of heart disease, suddenly, in his office in Philadelphia, on November 24th, 1902, in his sixty-fifth year. He is survived by his wife and his daughter, Mrs. John T. Gibson, of New York City.

For some years Mr. Wilson was a member and vestryman of St. Stephens Church, in Philadelphia. In the words of a resolution passed by this vestry:

> "Mr. Wilson was a man in whom the power and the beauty of the Christian religion conspicuously manifested themselves.* * * Confronted constantly with difficult problems, he knew no other standard of conduct than the example of Jesus and his own very delicate sense of honor. Just in all his relations, generous to a fault, truthful in word, pure in spirit, a loving husband, father, brother, and son—these moral virtues only added luster to the endowment of a naturally powerful mind, nor did his religious beliefs prove inimical to scientific attainments which placed him at the head of an exacting profession."

The foregoing gives but an outline of a very useful, honorable and well-rounded life. His was an exemplification of what great results a quiet, unostentatious, industrious life can accomplish in the scientific and industrial world, when accompanied by superior intelligence, a thorough education and a morality based upon strict religious principles.

The writer of this memoir would feel that he had not done the subject justice had he not, in closing, alluded briefly to the high moral purpose which actuated Mr. Wilson in all that he did; and to the religious faith and practice, which, from his early youth until the day of his death, were the controlling influences of his successful and happy life.

Mr. Wilson was elected a Member of the American Society of Civil Engineers on April 2d, 1873. He served as a Director from January 18th, 1888, to January 16th, 1889; and as Vice-President from January 17th, 1894, to January 15th, 1896.

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

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MAY, 1903.

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◆

The House of the Society is open from 9 A.M. to 10 P.M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PROCEEDINGS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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May 6th, 1903.—The meeting was called to order at 8.55 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, 123 members and 13 guests.

The minutes of the meetings of April 1st and 15th, 1903, were approved as printed in *Proceedings* for April, 1903.

A paper entitled "A Small Rock-Fill Dam," by H. de B. Parsons, M. Am. Soc. C. E., was presented by the author and illustrated with lantern slides. The Secretary presented a written communication from Samuel H. Lea, M. Am. Soc. C. E., and the subject was discussed further by Messrs. Foster Crowell, J. M. Goodell and the author.

A second paper, entitled "Deflections of Beams with Variable Moments of Inertia," by C. W. Hudson, M. Am. Soc. C. E., and a written communication from Irving P. Church, Assoc. Am. Soc. C. E., were presented by title, and the subject was discussed further by Mansfield Merriman, M. Am. Soc. C. E.

Ballots for membership were canvassed, and the following candidates elected:

As Members.

Frank Lloyd Averill, Washington, D. C.
Bernard Bienenfeld, San Francisco, Cal.
Thomas Avery Corry, Puebla, Mexico.
Carlton Rollin Dart, Chicago, Ill.
Ernest Howard Foster, New York City.
Kenneth Phipson Hawksley, London, England.
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Isaac Rich, Boston, Mass.
Edward Whitten Shedd, Providence, R. I.
Joseph Emory Sirrine, Greenville, S. C.
David Heikes Whitmer, Charleston, S. C.

As Associate Members.

Astolfo Bartoccini, New York City.
Charles Blaney Breed, Lynn, Mass.
Charles John Eld, Jr., St. Joseph, Mo.
James Welch Frazier, Cleveland, Ohio.
Charles Gartensteig, New York City.
Robert Ladd Gifford, Chicago, Ill.
Isaac Harby, Trenton, N. J.
Frederick Lawrence Hartigan, Chicago, Ill.
Don Hays, Kansas City, Mo.
Hermann Meriwether Knapp, Pencoyd, Pa.
Moses Jerome Look, Clinton, Mass.
Frank Howard Neff, Cleveland, Ohio.
Charles Edward Parsons, Glens Falls, N. Y.
Howard Platt Treadway, Kansas City, Mo.
Earnest Maitland Van Norden, Brooklyn, N. Y.
Hans von Unwerth, Kansas City, Mo.

The Secretary announced the election of the following candidates by the Board of Direction on May 5th, 1903:

As Associate.

Charles Henry Umstead, Portsmouth, N. H.

As JUNIORS.

ARTHUR HERBERT DIAMANT, New York City.
CHARLES LOUIS FOX, Wilkinsburg, Pa.
LOUIS ADAMS ROBB, Newark, N. J.
CHARLES RAPELYEA WYCKOFF, Jr., Brooklyn, N. Y.

The Secretary announced the following deaths:

WALTER S. GURNEE, elected Fellow May 10th, 1870; died April 17th, 1903.

EDWARD APPLETON GREENE, elected Member July 4th, 1888; died April 19th, 1903.

VICTOR M. CLEMENT, elected Fellow January 8th, 1890; died April 28th, 1903.

Adjourned.

May 20th, 1903.—The meeting was called to order at 8.45 P. M., President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, 76 members and 7 guests.

A paper entitled "The Economic Improvement of the Coosa and Alabama Rivers, in Georgia and Alabama," by D. M. Andrews, M. Am. Soc. C. E., was presented by the Secretary, who also read a communication on the subject from Capt. R. R. Raymond, Corps of Engineers, U. S. A.

The Secretary announced the death of the following members:

GEORGE RICHARDSON HARDY, elected Member November 7th, 1888; died April 2d, 1903.

EDMUND DORMAN LIBBY, elected Member May 6th, 1885; died April 24th, 1903.

WILLIAM GEORGE MCNEILL THOMPSON, elected Member July 2d, 1879; died May 12th, 1903.

Adjourned.

OF THE BOARD OF DIRECTION.

(Abstract.)

May 5th, 1903.—8.30 P. M.—President Noble in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Briggs, Croes, Jackson, Knap, Osborn, Osgood, Pegram and Schneider.

A special report was presented from a Committee appointed to consider the advisability of the discontinuance of advertisements in *Proceedings*, and the Secretary was instructed to discontinue all advertisements in the *Proceedings* of the Society, as soon as it can be done under existing contracts.

Applications were considered and other routine business transacted.

One candidate for admission as Associate, and four as Junior were elected.*

Adjourned.

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* See page 158.

ANNOUNCEMENTS.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day and Christmas Day.

MEETINGS.

Wednesday, June 3d, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper by Richard T. Dana, Assoc. M. Am. Soc. C. E., entitled "A New Safety Explosive," will be presented for discussion. This paper is printed in this number of *Proceedings.*

Wednesday, September 2d, 1903.—8.30 P. M.—A regular business meeting will be held. Ballots for membership will be canvassed, and a paper entitled "An Experimental Study of the Resistances to the Flow of Water in Pipes," by Augustus V. Saph, Assoc. Am. Soc. C. E., and Ernest W. Schoder, Jun. Am. Soc. C. E., will be presented for discussion. This paper is printed in this number of *Proceedings.*

Wednesday, September 16th, 1903.—8.30 P. M.—At this meeting a paper, by Elmo G. Harris, M. Am. Soc. C. E., entitled "Theory of Centrifugal Pumps and Fans: Analysis of their Action, with Suggestions for Designs," will be presented for discussion. This paper is printed in this number of *Proceedings.*

SEARCHES IN THE LIBRARY.

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many such searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction to the members who have made use of the resources of the Society in this manner has been expressed frequently, and leaves little doubt that, if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared to the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

Copies of all lists of references are filed, so that in many cases it is only necessary to make a typewritten copy, which reduces the cost of searches for members to a minimum.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and, whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

PROPOSED AMENDMENT TO THE CONSTITUTION.

The following proposed amendment to the Constitution has been received by the Secretary, and has been sent to all Corporate Members of the Society. In accordance with the provisions of Section 3 of Article IX of the Constitution, it will be considered at the Business Meeting of the Annual Convention at Asheville, N. C.

Amend the Constitution by striking out Sections 6, 7 and 8 of Article II, and the whole of Article III, and substituting therefor the following:

ARTICLE II.—Membership.

* * * * * * * *

6.—A Junior shall not be less than eighteen years of age, and his connection with the Society shall cease when he becomes thirty years of age, unless he be previously transferred to another grade. He shall have had active practice in some branch of engineering for at least two years, or he shall have graduated from a school of engineering of recognized standing. Persons who are in the Junior class at the time of the adoption of this Constitution shall not have their status changed by the provisions of this section.

7.—Honorary Members shall be chosen only from persons of acknowledged eminence in some branch of engineering or the sciences related thereto. There shall not be more than twenty at any one time.

8.—Fellows shall be contributors to the permanent funds of the Society, though they may not be eligible for admission as Corporate Members.

ARTICLE III.—Admissions and Expulsions.

1.—Honorary Members shall be proposed by at least ten members, and shall be elected only by a unanimous vote of the Board of Direction. A Past-President, or a member of the Board of Direction proposed for Honorary Membership, shall not be required to vote either for or against his own admission.

A person elected an Honorary Member shall be promptly notified thereof by letter. The election shall be cancelled if an acceptance is not received within six months after the mailing of such notice.

2.—An application for admission to the Society or for transfer from one grade to another shall embody a concise statement, with dates, of the candidate's professional training and experience; and shall be in a form and in such detail as may be prescribed by the Board of Direction. It shall be signed by the applicant, and shall contain a promise to conform to the requirements of membership, if elected. The applicant shall furnish the names of at least five Corporate Members to whom he is personally known. Each of these shall be requested by the Secretary to address a letter to the Board of Direction, on a form prescribed by said Board, stating the extent of the writer's personal knowledge of the applicant and of his professional work. If at least five of the Corporate Members named as references do not furnish the requisite endorsement, the Secretary shall call upon the applicant for additional names, and not until written communications shall have been received from at least five Corporate Members shall the application be considered by the Board.

Applications of engineers not resident in North America, and who may be so situated as not to be personally known to five Corporate Members, may be recommended for ballot by five members of the Board of Direction, after having secured evidence sufficient, in their opinion, to show that the applicant is worthy of admission.

3.—At stated periods, to be determined by the Board of Direction, there shall be issued to each member in any grade whose address is known, a list of all new applications received for admission or for transfer, which list shall be dated and shall contain a concise statement of the record of each applicant and the names of his references, with a request that members transmit to the Board any information in their possession which may affect the disposition of the applications. Not less than twenty days after the issue of such list, the Board of Direction shall consider these applications, together with any information in regard to the applicants that may have been received; may make further inquiries, if deemed expedient; shall classify the applicant with his consent, and on applications for admission may direct a ballot.

The Board shall have the power to transfer persons from a lower to a higher grade of membership, and shall notify the membership of its action.

4.—The ballots shall be letter-ballots, in a form to be prescribed by the Board of Direction. They shall be mailed to each Corporate Member whose address is known, and shall state the date on which the ballot is to be canvassed, which shall be not less than twenty days after the issue of the ballot. Twenty or more negative votes shall exclude from election. In case of exclusion, no notice thereof shall be entered on the minutes, but the candidate shall be notified.

5.—All elected candidates shall be duly notified and shall subscribe to the Constitution and Rules of the Society. Forms for these purposes shall be prescribed by the Board of Direction. If these provisions are not complied with within six months from the notification of election, such election shall be considered void, unless for special reason the time shall be extended by the Board of Direction.

Membership of any person shall date from the day of his election.

6.—Upon the written request of ten or more Corporate Members, that for cause therein set forth a person belonging to the Society be expelled, the Board of Direction shall consider the matter, and if there appears to be sufficient reason, shall advise the accused of the charges against him. He may, if he so desires, present a written defence which shall be considered at a meeting of the Board of Direction, of which he shall receive due notice. Not less than two months after such meeting, the Board of Direction shall finally consider the case, and if resignation has not been tendered, or a defence made which is satisfactory to the Board, it shall then notify the person that he will be expelled in one month, unless he elects to appeal from this decision. Appeals will be submitted to the Corporate Members by letter-ballot in a form to be prescribed by the Board of Direction. The ballot shall be accompanied by a statement of the charges, and of the action of the Board thereon, with such information as it deems proper, and also the statement of the person making the appeal. The ballot shall be canvassed by the Board not less than twenty days after its issue. A majority of the ballots cast will be required to sustain the action of the Board. The Board will notify the person and the Corporate Members of the result of the ballot. In case no appeal be made, the Board of Direction will expel the person, and notify him and the Corporate Members of its action.

7.—A member of any grade in the Society may resign his membership by a written communication to the Secretary, who shall present the same to the Board of Direction; when, if all his dues have been paid, his resignation shall be accepted.

8.—All persons elected and duly qualified, whose address on the records of the Society is within fifty miles of the Post Office in the City of New York, shall be deemed Resident; and those whose address is beyond that limit shall be deemed Non-Resident.

The classification of each person for the fiscal year as Resident or Non-Resident, shall be determined by the Records of the Society as they may appear on January 1st of that year.

The foregoing amendment is proposed by the following Corporate Members:

John F. Wallace,
David Sloan,
Ralph Modjeski,
J. W. Schaub,
Albert F. Reichmann,
C. A. Hasbrouck,
Frank J. Llewellyn,
Charles L. Strobel,
Geo. F. Swain,
William Jackson,
John E. Cheney,
S. Everett Tinkham,

Geo. S. Davison,
Emil Swensson,
J. A. Atwood,
W. C. Hawley,
W. G. Wilkins,
Josiah A. Briggs,
J. J. R. Croes,
A. Noble,
H. S. Haines,
Jos. O. Osgood,
Geo. H. Pegram,
Edw. P. North.

ANNUAL CONVENTION OF 1903.

The Thirty-fifth Annual Convention will be held at Asheville, N. C., June 9th, 10th, 11th and 12th, 1903.

The arrangements for the Convention are in the hands of the following Committees:

Committee of the Board of Direction.

J. James R. Croes, *Chairman.*

George H. Pegram,
Chas. Warren Hunt.

Local Committee.

J. L. Ludlow, *Chairman.*

William Cain,
Wilbur F. Foster,
George W. Frank,
J. C. Guild,
J. N. Hazlehurst,
W. B. W. Howe,

W. A. Leland,
J. Imbrie Miller,
J. A. Montgomery,
E. T. D. Myers,
Arthur Pew,
George O. Tenney,

Nisbet Wingfield.

The following programme has been arranged:

Tuesday, June 9th, 2.00 P.M. Opening Session.—Address of Welcome by the Hon. Theodore F. Davidson.

Business Meeting: The question as to the time and place for holding the next Annual Convention will be discussed, and a proposed amendment to the Constitution will be taken up in regular course. It is also probable that there will be an informal consideration of the proposed co-operation of the Society with the other National Societies and the Engineer's Club of New York, in the matter of a Joint Engineering Building.

8.30 P. M. Second Session.—Annual address, by Alfred Noble, President, Am. Soc. C. E.

Wednesday, June 10th, 10.00 A. M. Third Session.—Professional Discussion on Topics Nos. 1, 2 and 3.

Afternoon.—An Excursion by trolley around Asheville and a visit to the Swannanoa Country Club has been arranged for this afternoon.

9.00 P. M.—Reception.—The Hon. Charles B. Aycock, Governor of North Carolina, has accepted the invitation of the Local Committee to meet the members and guests of the Society this evening.

Thursday, June 11th, 10.00 A. M. Fourth Session.—Professional Discussion on Topics Nos. 4, 5 and 6.

3.00 P. M.—Excursion to Sunset Mountain. By invitation of Richard S. Howland, Esq., President, Asheville and Craggy Mountain Railroad Company, the Society will visit Overlook Park, on Sunset Mountain, spending the afternoon and remaining there until after sunset. R. H. Tingley, M. Am. Soc. C. E., will be with the party, and will describe the interesting features of the construction of this road at the Pavilion, on arrival at the Park.

At 5 P. M. the party is invited to a Barbecue by Mr. Howland, and the return to the Hotel will be made about 9 P. M.

Evening.—Concert.

Friday, June 12th, 10.00 A. M. Fifth Session.—Adjourned Business or Professional Meeting, if necessary; otherwise the morning will be free for individual trips to points of interest in the vicinity.

1.30 P. M.—A drive through "Biltmore," the estate of George W. Vanderbilt, Esq., has been arranged for this afternoon.

9.00 P. M.—Informal dancing in the ballroom of the Battery Park Hotel.

TOPICS FOR INFORMAL DISCUSSION.

Topic No. 1. Timber Tests.

This discussion will be opened by representatives of the U. S. Bureau of Forestry (see *Proceedings* for April, 1903, p. 133).

Topic No. 2. Sewage Purification.

Rudolph Hering, M. Am. Soc. C. E., will introduce this subject.

Topic No. 3. In the treatment of the Mississippi River, is the Levee Theory Justified by Experience?

Discussion on this subject will be introduced by B. M. Harrod, Past-President, Am. Soc. C. E.

Topic No. 4. Is it possible to make Concrete which will be Impervious to Water? If so, what is the best method?

This discussion will be introduced by William B. Landreth, M. Am. Soc. C. E.

Topic No. 5. What is the effect of Sea-Water upon Steel, and upon Steel and Concrete used in Combination, and is the use of Steel in Sea-Water admissible?

Topic No. 6. In view of the increasing weights of Rolling Stock, for what loadings should Railroad Bridges be designed?

Henry W. Hodge, M. Am. Soc. C. E., will open this discussion.

ACCESSIONS TO THE LIBRARY.

From April 8th to May 12th, 1903.

DONATIONS.*

A MANUAL OF FIELD AND OFFICE METHODS

For the Use of Students in Surveying. By William D. Pence and Milo S. Ketchum. Third Edition. Leather, 7 x 5 ins., 252 pp., illus. New York, Engineering News Publishing Co., 1902. $2.00.

The preface states that in preparing this manual the following points have been kept especially in view: (1) To provide a simple and comprehensive text designed to anticipate and supplement, rather than replace, the usual elaborate treatise. (2) To bring the student into immediate familiarity with approved surveying methods. (3) To cultivate the student's skill in the rare arts of keeping good field notes and making reliable calculations. This third edition is issued to meet the call for the manual at various technical institutions and from practicing engineers. With a view to increase the value of the book, both for teaching and for reference purposes, various revisions and additions have been made. Among these are the full scale samples of field notes on the inset sheet at the back of the book. The Contents are: General Instructions; The Chain and Tape; The Compass; The Level; The Transit; Topographic Surveying; Land Surveying; Railroad Surveying; Errors of Surveying; Methods of Computing; Freehand Lettering.

THE PRINCIPAL SPECIES OF WOOD:

Their Characteristic Properties. By Charles Henry Snow, M. Am. Soc. C. E. Cloth, 10½ x 7 ins., 16 + 203 pp., illus., 39 plates. New York, John Wiley & Sons, 1903. $3.50.

The preface states that this book is a brief, untechnical presentation of the general features characterizing economically important species of wood. It is the result of notes originally brought together from many already existing sources and later augmented, and verified, as far as possible for present use, by personal observation. This work is intended for those who are not foresters or botanists, but who use woods or desire knowledge of their distinguishing properties. Allusion to trees, historical and other references, aside from those directly regarding woods, are made for completeness and in order to mark, distinguish, or separate the species. The book is divided into three parts: Introduction; Broadleaf or Hardwoods; Needleleaf or Softwoods. There is an index of eleven pages.

IRRIGATION INSTITUTIONS.

A Discussion of the Economic and Legal Questions Created by the Growth of Irrigated Agriculture in the West. By Elwood Mead. Cloth, 7½ x 5 ins., 11 + 392 pp., illus. New York, The Macmillan Company, 1903. $1.25. (Donated by the Author.)

The preface states that this work is based on twenty years' experience in the development of irrigated agriculture in the arid West. Fifteen years of this time were devoted to the study and administration of irrigation laws as assistant state engineer of one commonwealth and territorial and state engineer of another. The duties of these positions brought the writer into personal and official relations with all classes of men to whom the problems of irrigation were of vital interest. These included not only farmers, ditch builders, and investigators in irrigation securities, but also legislators and jurists who were shaping the legal principles which are to control the distribution and use of Western water supplies. The Department of Agriculture is studying the methods of distributing and using water in order to promote its more skillful and effective use, and is inquiring into the social and legal questions created by the use of streams in irrigation, both in this country and in other lands. From its beginning the writer has been in charge of these investigations. The convictions expressed have been more largely shaped by what has been seen than by what has been read. The Contents are: Introduction; Land Laws of the Arid Region; The Beginnings of Irrigation; The Doctrine of Appropriation; Contract Water Rights; Measurement of Water; The Duty of Water; Irrigation in Colorado; Irrigation in California; Irrigation in Utah; Irrigation in Wyoming; Irrigation in Other Arid and Semi-arid States; Riparian and Interstate Rights; Methods and Measures Needed for Future Development. There is an index of eight pages.

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* Unless otherwise specified, books in this list have been donated by the Publishers.

COMPRESSED AIR INFORMATION;

Or, A Cyclopedia Containing Practical Papers on the Production, Transmission and Use of Compressed Air. Edited by W. L. Saunders, M. Am. Soc. C. E. Cloth, 9 x 6 ins., 1 175 pp., illus. "Compressed Air," New York, copyright 1903. $5.00. (Donated by the Editor.)

This publication has been called for by many inquiries addressed to the editor of *Compressed Air* asking for various papers, some of them original and others compiled, which have been published in that magazine during the first five years of its existence. The supply of the early issues having been long since exhausted and the demand continuing, an effort has been made to present in a single book of reasonable size all the important practical information contained in the first five volumes. No attempt has been made to introduce new matter, but the various papers, editorials and notes have been selected and arranged under suitable headings so that any one seeking information on this subject may be afforded facilities for finding it properly classified. There is an index of seven pages.

SILICO-CALCAREOUS SANDSTONES.

Building Stones from Quartz-Sand and Lime. Chemical and Technical Principles of Their Manufacture According to the Situation, Erection, and Management of Brick Works. By Ernst Stöffler. Paper, 36 pp., illus., 5 plates. N. Y., Spon & Chamberlain. $1.00.

This book describes in detail several processes for making artificial building stone and brick from mixtures of silicious sand and lime; the hardening of the stone being obtained either in the open air or by steam under high or low pressure.

RULES FOR RAILWAY LOCATION AND CONSTRUCTION

Used on the Northern Pacific Railway. By E. H. McHenry, M. Am. Soc. C. E. With an Additional Chapter on Estimating Overhaul in Earthwork, Compiled by H. P. Gillette. Cloth, 8 x 5 ins., 88 pp. New York, The Engineering News Publishing Co., 1903. $1.00.

The Chapter headings are: Construction and Engineering Departments; Location; Surveys and Construction; Track and Ballast; Bridges and Culverts; Accounting and Miscellaneous; Supplies; Estimating Overhaul in Earthwork.

ENGINEERING STUDIES. Parts III, IV and V.

By Charles Evan Fowler, M. Am. Soc. C. E. Paper, 10½ x 7 ins., 3 vol., illus. New York, The Engineering News Publishing Co., 1901–1903. 25 cents per vol.

This is a collection of photographic views of engineering works to which short descriptions and criticisms are appended. Parts I and II have appeared previously. The Contents are: Part III. English Stone Arches; Part IV. French Stone Arches; Part V. German and Austrian Stone Arches.

THE IMPROVEMENT OF RIVERS.

A Treatise on the Methods Employed for Improving Streams for Open Navigation, and for Navigation by Means of Locks and Dams. By B. F. Thomas, M. Am. Soc. C. E., and D. A. Watt, M. Am. Soc. C. E. Cloth, 12 x 9½ ins., 14 + 356 pp., illus., 92 plates. New York, John Wiley & Sons, 1903. $6.00 net; postage 47 cents additional.

The object of this work is to provide in concise form a description of the various systems used in bettering the conditions of navigable streams, together with the methods usually adopted for their design and execution. It has been the endeavor to include all the important points of design and construction which are likely to be met, and all calculations have been simplified so as to bring them within the range of those who are not thoroughly educated, yet whose services are most valuable on river work by reason of their practical experience and good judgment. The authors believe that, as this branch of engineering is virtually untaught in the engineering schools of this country, the advent of this treatise will widen the scope of the usual engineering course and prepare students for entering the engineer service of the Government through the junior engineer grade of the civil service. With this object in view hydrographic surveys and reports and examinations have been treated at some length. The Contents are: Introduction; Characteristics of Rivers; Preliminary Examinations and Surveys;

Topographical Surveys and Leveling; Hydrographic Surveys; Removal of Bars and Other Obstructions; Regularization; Dikes and their Effects; Protection of Banks; Levees; Storage Reservoirs; Improvement of River Outlets; General Design and Construction of Works for Creating Slack Water; Locks; Lock Gates and Valves; Fixed Dams; Movable Dams; Needle Dams; Chanoine Wicket Dams; Gate, Curtain and Bridge Dams; Shutter and A-Frame Dams; Drum Wickets and Bear-Traps; Recent Construction of Movable Dams; Dimensions, etc., of Locks and Dams of Certain Rivers; Specifications; Laws for the Protection and Preservation of the Navigable Waters of the United States. There is an index of six pages.

ELECTRICITY AS APPLIED TO MINING.

By Arnold Lupton, M. Inst. C. E., M. I. Mech. E., M. Inst. E. E.; G. D. Aspinwall Parr, M. Inst. E. E., A. M. I. Mech. E., and Herbert Perkin, M. I. M. E. Cloth, 9 x 6 ins., 7 + 280 pp., illus. New York, D. Van Nostrand Co., 1903. $3.50.

The aim of the authors of this volume has been to present the leading truths and main principles of electricity and electrical engineering without going into great detail, their intention being that, for further information on the theory and practice of the subjects of electrical and mining engineering, recourse should be had to some of the many standard works already in existence. They have been unable, in the space at their disposal, to deal with all the varieties of machines and appliances now in use, typical examples of good practice being considered sufficient for the present purpose. The chapter headings are: Introductory; Dynamic Electricity; Driving of the Dynamo; The Steam Turbine; Distribution of Electrical Energy; Starting and Stopping Electrical Generators and Motors; Electric Cables; Central Electrical Plants; Electricity Applied to Pumping and Hauling; Electricity Applied to Coal-Cutting; Typical Electric Plants Recently Erected; Electric Lighting by Arc and Glow Lamps; Miscellaneous Applications of Electricity; Electricity as Compared with other Modes of Transmitting Power; Dangers of Electricity. There is an index of ten pages.

CONDUCTORS FOR ELECTRICAL DISTRIBUTION;

Their Materials and Manufacture, the Calculation of Circuits, Pole-Line Construction, Underground Workings, and other Uses. By F. A. C. Perrine, M. Am. Inst. E. E. Cloth, 9 x 6 ins., 7 + 287 pp., illus. New York, D. Van Nostrand Co., 1903. $3.50.

The author states in the preface that this book represents the results of over ten years of work as a manufacturer of insulated wires and cables, as an engineer advising concerning their installation and finally as a teacher of electrical engineering. Over eight years has been consumed in actually writing and revising. The original rough cast was published in *Electrical Engineering*, the last chapter appearing three years ago. The author has made a final revision and has presented the whole as a book through the belief that by the previous publication he has been enabled to eliminate from its pages descriptions of materials and methods that are not founded on safe engineering principles. The Contents are: Conductor Materials; Alloyed Conductors; The Manufacture of Wire; Wire-Finishing; Wire Insulation; Cables; Calculation of Circuits; Kelvin's Law of Economy in Conductors; Multiple Arc Distribution; Alternating Current Calculation; Overhead Lines; The Pole Line; Line Insulators; Underground Conductors. There is an index of seven pages.

DIRECTORY OF AMERICAN CEMENT INDUSTRIES AND HAND-BOOK FOR CEMENT USERS.

Edited by Charles Carroll Brown, M. Am. Soc. C. E. Cloth, 9 x 6 ins., 645 pp. Municipal Engineering Company, Indianapolis, 1901. (Donated by the Editor.)

The publication of this Directory is the direct result of the many demands for information upon all questions connected with the manufacture, sale, and use of cement which have been made upon the *Municipal Engineering Magazine*, and of the conclusion drawn that the time has now arrived for the publication of such a book, giving more particularly from the practical and commercial standpoints the answers to all the classes of questions which those interested in cement are asking. The Contents are: Preface; Introduction; Testing of Cement; Specifications for Cement; The Uses of Cement; Specifications for the Use of Cement; Data for Estimates of Cement Work; Cement Laboratories; Freight Rates on Cement; Explanation of Reference Notes; Description of Works and of Processes for the Manufacture of Cement; Directory of Cement Brands; Directory of General Sales Agents; Classified Directory of Cement Dealers and Users; Dealers in Cement; Contractors and Large Users of Cement; Engineers, Architects and Other Supervisors of the Use of Cement; Workers in Cement; Cement Tests and Analyses; Machinery and Supplies for Cement Plants; Dealers in Lime and Plaster; Manufacturers of Lime; Manufacturers of Plaster. There is an index of eight pages.

EXPERIMENTS ON THE FLEXURE OF BEAMS,

Resulting in the Discovery of New Laws of Failure by Buckling. By Albert E. Guy. Cloth, 8 x 6 ins., 122 pp., illus. New York, D. Van Nostrand Company, 1903. $1.25 net.

The preface states that the analogy of the failure of the compression side of a beam by buckling to the method of failure of a long column was, of course, long ago remarked. but it is believed that there has been no previous attempt—certainly no successful attempt—to connect the two by a formula. Mr. Guy's experiments have been successful beyond any reasonable expectation in connecting them and in showing that Euler's formula for long columns is, in fact, the fundamental formula which lies at the base of the whole subject. The Contents are: Introduction; A Simple Problem; The Transverse Shearing; The Longitudinal Shearing; The Deflection of the Beam; Experiments; Corollary; That Simple Problem; The Best Form of Section; The Central Web; The Width of the Section; Example; Solution; The Shape of the Beam; The New Law; Examples.

Gifts have also been received from the following:

Adams, Arthur L. 1 pam.
Alaska Mexican Gold Min. Co. 2 pam.
Alaska United Gold Min. Co. 1 pam.
Allen, Kenneth. 1 pam.
Arlington, Mass.—Town Officers. 17 vol.
Assoc. des Ingénieurs Sortis des Écoles Speciales de Gand. 1 no.
Averill, F. L. 1 bound vol.
Baldwin, Wm. H. 1 pam.
Bangor, Me.—City Clerk. 19 vol.
Bay City, Mich.—Water Dept. 1 pam.
Berg, Walter G. 1 pam.
Bessemer, Ala.—City Clerk. 3 pam.
Bixby, W. H. 1 pam.
Boston, Mass.—City Auditor. 16 bound vol.
Braumüller, Wilhelm. 1 pam.
Bridgeton, N. J.—City Comptroller. 1 pam,
Brookline, Mass.—Water Board. 1 pam.
Brooklyn, N. Y.—Pub. Lib. 1 pam.
Brooks, Frederick. 2 pam.
Brown, C. C. 1 bound vol.
Canada Southern Ry. Co. 1 pam.
Carter, W. J. 2 bound vol.
Chattanooga, Tenn.—City Engr. 1 vol., 2 pam.
Church, C. F. 4 pam.
Cincinnati, Ohio—City Auditor. 20 bound vol.
Cincinnati, Ohio—Water Dept. 1 pam.
Coll. of the City of N. Y. 26 pam.
Colo.—Agri. Exper. Station. 1 vol.
Columbian Univ. 9 vol.
Columbus, Ohio—City Clerk. 10 bound vol.
Concord, N. H.—City Engr. 6 pam.
Concord, N. H.—Water Dept. 1 pam.
Conn.—State Board of Health. 1 bound vol.
Cornell Univ. 1 vol.
Corthell, E. L. 1 pam.
Davis, C. R. 2 pam.
Des Moines, Iowa—City Engr. 1 pam.
Eddy, Harrison P. 1 pam.
Eng. Soc., School of Practical Science. 1 vol.
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BY PURCHASE.

Electrotechnik in Einzeldarstellungen. Unter Mitwirkung hervorragender Fachmänner Herausgegeben von Dr. Gustav Benischke. Vol. I. Braunschweig, Friedrich Vieweg und Sohn, 1902.

Die Wechselstromtechnik. Herausgegeben von E. Arnold. Vol. I. Berlin, Julius Springer, 1902.

A Systematic Method of Calculating the Dimensions of Direct-Current Dynamo-Electric Machines. By Carl Kinsley. Chicago, The University of Chicago Press, 1903.

Secondary Batteries: Their Theory, Construction and Use. By E. J. Wade. New York, The D. Van Nostrand Co.; London, "The Electrician" Printing and Publishing Company.

Wireless Telegraphy. A Popular Exposition. By G. W. Tunzelmann. Third Edition. London, The Office of "Knowledge," 1902.

Supplement to the Directory to the Iron and Steel Works of the United States. Containing a Classified List of Leading Consumers of Iron and Steel in the United States. Compiled by the American Iron and Steel Association. Corrected to January, 1903. Philadelphia, The American Iron and Steel Association, 1903.

Proceedings of the Purdue Society of Civil Engineering. 1896, 98, 1900–01. Purdue University, Lafayette, Ind., 1896–1901.

First Annual Report of the Wisconsin Engineers' Society, Containing Papers Read at the Annual Meeting Held at Appleton, March 30, 1897. No place, 1897.

Proceedings of the Annual Meeting of the Indiana Engineering Society, 1893 and 1896. South Bend, 1893–96.

Proceedings of the Iowa Civil Engineers' and Surveyors' Society at their Ninth Annual Meeting held at Ottumwa, Iowa, January 20–21, 1897. Glenwood, Iowa, 1897.

Eighteenth Annual Report of the Ohio Society of Surveyors and Civil Engineers, being the Transactions of the Society at its Eighteenth Annual Meeting Held in Columbus, Ohio, January 18, 19 and 20, 1897. Columbus, 1897.

Annual Report of the Association of Ontario Land Surveyors, 1889, 1892–1900. Toronto, 1889–1900.

Notes on Concrete and Works in Concrete. Especially written to Assist those Engaged upon Public Works. By John Newman. Second Edition, Revised and Enlarged. London, E. & F. N. Spon; New York, Spon & Chamberlain, 1894,

Pumps and Pump Motors. A Manual for the Use of Hydraulic Engineers. By Philip R. Bjorling. 2 vol. London, E. & F. N. Spon; New York, Spon & Chamberlain, 1895.

The Principles, Construction and Application of Pumping Machinery (Steam and Water Pressure). With Practical Illustrations of Engines and Pumps applied to Mining, Town Water Supply, Drainage of Lands, etc., also Economy and Efficiency Trials of Pumping Machinery. By Henry Davey. London, Charles Griffin & Company, Limited; Philadelphia, J. B. Lippincott Company, 1900.

SUMMARY OF ACCESSIONS.

April 8th to May 12th, 1903.

Donations (including 41 duplicates and 1 number completing volume of periodical)	385
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Total	412

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ADDITIONS.

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Moncure, William	May 5th, 1903

DEATHS.

Card, William Warren	Elected Member, September 5th, 1883; died April 4th, 1903.
Clement, Victor M.	Elected Fellow, January 8th, 1890; died April 28th, 1903.
Greene, Edward Appleton	Elected Member, July 4th, 1888; died April 19th, 1903.
Gurnee, Walter S.	Elected Fellow, May 10th, 1870; died April 17th, 1903.

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(April 8th to May 12th, 1903.)

NOTE.—*This list is published for the purpose of placing before the members of the Society the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS.

In the subjoined list of articles references are given by the number prefixed to each journal in this list.

(1) *Journal*, Assoc. Eng. Soc., 257 South Fourth St., Philadelphia, Pa., 30c.
(2) *Proceedings*, Engrs. Club of Phila., 1122 Girard St., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Monadnock Block, Chicago, Ill.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Technology Quarterly*, Mass. Inst. Tech., Boston, Mass., 75c.
(8) *Stevens Institute Indicator*, Stevens Inst., Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(10) *Cassier's Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *The Engineering Record*, New York City, 12c.
(15) *Railroad Gazette*, New York City, 10c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Street Railway Journal*, New York City, 35c.
(18) *Railway and Engineering Review*, Chicago, Ill., 10c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 10c.
(21) *Railway Engineer*, London, England, 25c.
(22) *Iron and Coal Trades Review*, London, England, 25c.
(23) *Bulletin*, American Iron and Steel Assoc., Philadelphia, Pa.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *American Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England.
(27) *Electrical World and Engineer*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, $1.
(29) *Journal*, Society of Arts, London, England, 15c.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium.
(31) *Annales de l' Assoc. des Ing. Sortis des École Spéciales de Gand*, Brussels, Belgium.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France.
(34) *Portefeuille Économique des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *La Revue Technique*, Paris, France.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Railway Master Mechanic*, Chicago, Ill., 10c.
(40) *Railway Age*, Chicago, Ill., 10c.
(41) *Modern Machinery*, Chicago, Ill., 10c.
(42) *Transactions*, Am. Inst. Elec. Engrs., New York City, 50c.
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(44) *Journal*, Military Service Institution, Governor's Island, New York Harbor, 50c.
(45) *Mines and Minerals*, Scranton, Pa., 20c.
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(47) *Mechanical Engineer*, Manchester, England.
(54) *Transactions*, Am. Soc. C. E., New York City, $5.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $5.
(57) *Colliery Guardian*, London, England.
(58) *Proceedings*, Eng. Soc. W. Pa., 410 Penn Ave., Pittsburg, Pa., 50c.
(59) *Transactions*, Mining Inst. of Scotland, London and Newcastle-upon-Tyne.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *American Manufacturer and Iron World*, 59 Ninth St., Pittsburg, Pa.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 20c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 15c.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England.

LIST OF ARTICLES.

Bridge.

Essentials Necessary for Successful Practice in Bridge Engineering. J. E. Greiner, M. Am. Soc. C. E. (Extracts from lecture delivered before students of Cornell Univ.) (13) Apr. 9.
The Rio Grande Bridge of the El Paso & Southwestern R. R. near El Paso, Tex.* R. A. Thompson. (13) Apr. 9.
The Des Moines River Viaduct of the Mason City & Fort Dodge R. R., at Fort Dodge, Ia.* H. C. Keith. (13) Apr. 9.
New Railway Bridge over the Tyne.* (12) Apr. 10.
Types and Details of Bridge Construction.* Frank W. Skinner. (14) Serial beginning Apr. 11.
Theory and Calculation of the Two-Hinged Spandrel-Braced Arch. Alex. Rice McKim. (14) Apr. 11.
Drawbridge Calculations. Edward Godfrey. (13) Apr. 16.
The Paderno Viaduct, Italy.* (12) Serial beginning Apr. 17.
The Ouachita River Bridge, Missouri Pacific Railway.* (40) Apr. 17.
A Steel Truss Highway Bridge with Concrete Floor.* (14) Apr. 25.
Erection of the Manhattan Approaches to the Williamsburg Bridge.* (14) May 9.
Le Viaduc du Viaur (Ligne de Carmaux à Rodez).* R. Godfernaux. (30) Apr.

Electrical.

The Arcophone. R. A. L. Snyder. (42) Mar.
Telephone Service. S. J. Larned. (4) Apr.
The Development, Equipment and Operation of the Sub-Stations and Distributing Systems of the Chicago Edison Co. and Commonwealth Electric Co. Ernest F. Smith. (4) Apr.
Grounding of Alternate Current Systems. Geo. N. Eastman. (4) Apr.
The Engineering of Illumination.* Van Rensselaer Lansingh. (4) Apr.
Electricity Works of Tunbridge Wells.* (26) Apr. 3.
On the Application of Three-Phase Motors to the Electrical Driving of Workshops and Factories.* A. C. Eborall. (29) Apr. 3.
Laboratory Electric Furnace Equipment, Owens College, Manchester, England.* (27) Apr. 4.
Electrical Manufacture of Steel in Sweden.* G. Lindman. (27) Apr. 4.
Electrical Extensions at Willesden. (12) Serial beginning Apr. 10.
Sheet Steel for Static Transformers. Walter S. Moody. (27) Apr. 11.
De Forest Wireless Telegraph System. A. Frederick Collins. (27) Apr. 11.
Wireless Telegraphy in the United States. E. Guarini. (26) Serial beginning Apr. 17.
Some Notes on Electrically Driven Winding Engines.* (57) Apr. 17.
Vancouver Transmission Plant.* Wyatt H. Allen. (27) Apr. 18.
The Lodge-Muirhead System of Wireless Telegraphy.* H. C. Fyfe. (46) Apr. 18.
Insulating Materials: A Field for the Chemist. Max von Recklinghausen. (Paper read before the Amer. Electrochemical Soc.) (13) April 23.
Electric Safety Fuses. (26) Apr. 24.
The Development of Marconi's System of Wireless Telegraphy.* Emile Guarini. (19) Serial beginning Apr. 25.
Telephone Exchanges.* Arthur V. Abbott. (27) Serial beginning April 25.
Corrosion of Metals by Electrolysis. A. A. Knudson. (Abstract of paper read before the Amer. Electrochemical Soc.) (27) Apr. 25.
Development in Telephone Switchboard Equipment at Bloomington, Ill.* (27) Apr. 25.
Core Type Transformers.* (27) Apr. 25.
General Specifications for the Construction of Telephone Aerial Lines.* (27) Apr. 25.
The Telegraphone and the British Post-Office.* Herbert C. Fyfe. (46) Apr. 25.
The Cascade Water, Power and Light Co., Cascade, B. C., Canada. W. G. McConnon. (27) Apr. 25; (18) Apr. 25; (14) May 2.
Notes on Recent Electrical and Scientific Developments Abroad.* William J. Hammer. (3) Serial beginning May.
Small Water Powers with High Heads for Electric Lighting.* Thoburn Reid. (10) May.
The Central Avenue Power Station (Kansas City).* H. S. Badger and G. E. Schreiber. (64) May.
The Motive Power of the Future.* Horace D. B. How. (Abstract of paper read before the South Wales Inst. of Engrs.) (22) May 1.
The New Aberdeen Electricity Works.* (26) May 1.
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AMERICAN SOCIETY OF CIVIL ENGINEERS.

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PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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A NEW SAFETY EXPLOSIVE.

BY RICHARD T. DANA, ASSOC. M. AM. SOC. C. E.

TO BE PRESENTED JUNE 3D, 1903.

Since the days of Nobel's invention of dynamite, his mixture, or a close approximation to it, has been used in practically all industrial work requiring the use of a high explosive—until very recent years.

For some ten or fifteen years in Europe, and two or three years in this country, there have been coming into use some explosive compounds of the nitro-substitution class, so-called, which are claimed to have advantages over the dynamites, from the standpoints of non-freezability, safety in handling, and certain other points, varying with the particular compound.

In the summer of 1900, while on the New York Division of the Erie Railroad, the writer had occasion to recommend for trial an explosive having picric acid and sodium nitrate for the principal constituents, and which was advertised to be rather higher in power than 40% dynamite. There had recently been an explosion of dynamite in storage, for which no definite cause was discovered, and which was rather expensive; moreover, the 40% dynamite was thought to be a little weak for the rock to be handled, which was a hard metamorphic rock, called by the natives "bastard trap."

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

A box of this material, known as Joveite, was ordered, and careful tests made under the supervision of the writer, the results of which, with some supplementary ones which he made later, were as follows:

The material is a yellow powder, resembling corn meal, put up in cartridges similar to those of dynamite in size and shape. A quantity of the powder was placed on a rail and hammered with a sledge without result until after several trials a spark was struck, and the powder remaining on the rail burned up with about the rapidity of celluloid.

A stick was then fired into with a shot-gun without result, and then small quantities of equal bulk of Joveite and 40% dynamite were detonated on the corners of a wrought-iron plate, with a view to determine the intensity of explosion. The indication from two trials was that dynamite was a little the quicker. Several trials were made by mudcapping, in comparison with 40% dynamite, and no difference in the results detected. The powder was then used in the rock itself, and gave results practically identical, as far as work was concerned, with those from dynamite. Its general use was then recommended, and has been continued up to the present.

Joveite is somewhat lighter, bulk for bulk, than dynamite, the proportion being 2 to 3, and it was found that it would do just about the same amount of execution in the rock, bulk for bulk. This made the cost the same, or a little less, the price per pound being 11 or 12 cents. The material is a dry powder and therefore will not freeze. It has been used in the coldest weather without noticeable variation in strength or sensitiveness, and, as far as the writer knows, has never exploded accidentally.

As soon as the men became familiar with the material they began to take liberties with it, such as tamping it heavily in the hole. This gave rise to trouble, in the first few months of its use, for the cartridge in which it was put up was made of paper and frequently burst under this treatment, with the result that the powder was not properly confined in the hole and there were a number of cases of imperfect detonation. The powder is not easily detonated when wet, and, loaded in wet holes, its use was very unsatisfactory, dynamite being substituted; but, recently, the manufacturers have devised a water-tight cartridge with a cloth fiber, which admits of considerable tamping and distortion without becoming pervious. Loaded in this manner, its use is eminently satisfactory.

The men in the quarry had complained of the well-known effect of the nitro-glycerine fumes from dynamite. The writer made a careful examination of Joveite, in this particular, and did not succeed it getting a suspicion of headache from it, and he has heard no complaints in this respect, with one exception, which was at second-hand, and which he was unable to verify. When detonated, it has a distinctly perceptible odor, which is slightly suggestive of nitro-glycerine, but is not unpleasant.

The detonation is accomplished in the ordinary manner, by the use of a single-strength fulminate-of-mercury cap, either with a powder fuse or fired from a battery. In firing with a fuse, some trouble was experienced occasionally, from the fact that the material is inflammable. When the cap was inserted too far into the cartridge, the fire from the fuse itself would sometimes be communicated to the powder before the primer was fired, which resulted in a "flower pot." This was obviated by the use of electric fuses, or, on the other hand, by a little care in the setting of the powder fuse. It is to be regretted that in many cases owners of quarries still use the old Bickford type of fuse.

In the spring following the disastrous dynamite explosion at Forty-second Street, in New York City, the manufacturers of Joveite held a public exhibition of their product, at which they ignited a pile of boxes containing 600 lbs. of the explosive. The exhibitors said that their only feeling of nervousness was lest by some faint chance a mercury primer might have got among the boxes. The crowd stood about 80 yds. from the boxes, and it must be confessed that while the mass was taking fire the situation was decidedly interesting. About 150 or 200 lbs. of the explosive burned up immediately, scorching and charring the remaining boxes, which had not been broken open. These were then broken open and lighted, when the mass blazed up and was entirely consumed, with the evolution of a dense white smoke, and no very noticeable odor. Another interesting demonstration* was that of dropping a 200-lb. weight upon a box of the explosive in which were scattered bits of iron, nails, etc., resting on an anvil. The fall was about 30 ft., producing sufficient heat of friction and impact to ignite the powder.

A very important point, which the writer does not think has yet been established definitely, is whether this explosive can be made to detonate without flame. It is claimed, by the manufacturers of a rival powder, that their product is absolutely flameless, and can be used safely in mine workings where there is a large quantity of dust, fire damp, etc., in the air. The manufacturers of Joveite say that, under special conditions, where a perfect detonation can be effected, they think that there is no flame from their product. In a mine, under service conditions, they do not claim entire immunity from flame. It has not yet been demonstrated, to the writer's satisfaction, that any explosion accompanied by evolution of heat is not, under some conditions, likely to be also accompanied by flame. Moreover, the question is still open whether fire damp or mine dust, with a proper admixture of gases, may not be detonated by shock. In the writer's opinion, the most instructive experiments with Joveite were witnessed by him at the company's laboratory in March, 1903.

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* Mentioned in a letter by the writer, in *Engineering News*, January 22d, 1903.

Two sticks of the material were placed on the ground, end to end, the adjacent ends being about 3 ins. apart, and one stick only detonated. Afterward, the other stick was detonated by itself. Two sticks were placed side by side, 4 ins. apart, and one detonated without detonating the other. A stick was placed on the ground, and a mercury fulminate cap of single strength was fired ½ in. from and pointed at the center of the stick. The blast from the cap tore open the cartridge and threw out some of the powder without detonating it.

A quantity of the powder was sprinkled upon a red-hot iron plate. As the particles touched the plate they flashed into flame with a sputtering, or burned quietly until consumed.

A small quantity of the powder was placed in a small glass tube which was in turn inserted into the middle of another tube and placed between the poles of an extremely powerful spark machine. The machine was easily capable of generating a continuous spark 14 ins. long, and was so powerful that it could not be operated for more than a few seconds at a time without burning out the heavy rubber insulation from the copper wires. When the spark was generated, it perforated the smaller glass tube, about 1½ ins. in length, longitudinally. The effect of the spark on the explosive was to fuse it and burst the tube. Most of the Joveite was burned, and none of it detonated.

A description of the process of manufacture of Joveite, kindly furnished by Mr. Frank P. Harris, Chemist of the company, is as follows:

The powder is composed of a mixture of nitro-naphthalenes, nitro-phenols, and a metallic nitrate.

The proportions are as follows:

	No. 1.	No. 2.	No. 3.
Nitro-naphthalenes	9	10	8
Nitro-phenols	14	24	30
Metallic nitrate	77	66	62

Picric acid is used for the nitro-phenol, and is what gives the powder its yellow color. It should be noted, in passing, that this substance stains the hands of the workmen using it. The stains are almost impossible to avoid in using, unless the whole sticks, paraffined, are used, and are exceedingly difficult to remove with the ordinary materials at the workman's command. The yellow stains are not easily visible by artificial light. Picric acid is soluble in alcohol and ether.

The metallic nitrate is dried thoroughly by means of a rotating-drum dryer, screened, and conveyed to a steam-heated room to be kept from absorbing moisture.

The nitro-napthalenes are first melted in a steam-jacketed kettle, and stirred by paddle arms, at the temperature of boiling water. Then the nitro-phenols are put in and melted, and, finally, the metallic nitrate, in the form of a dry powder, is stirred thoroughly with the other ingredients. After a time allowed for thorough mixing, the powder is removed to mechanical screens and there granulated to a free-running powder.

By using the nitro-napthalenes in this way it is possible to melt the nitro-phenols at a safe temperature, while the presence of nitro-naphthalenes in the finished product renders it quite insensitive to shock. By coating the grains of the metallic nitrates with the mixture of the nitro ingredients, the nitrates become protected from the atmosphere as by a varnish, for, while the nitro-phenols are slightly soluble in water, they are not deliquescent.

The quality of the powder depends wholly on the purity of the ingredients and the intimacy with which they are mixed.

The granulated powder is then packed in shells of various lengths and diameters, made of strong cloth-lined paper, and dipped in a paraffine solution, which renders them water- and moisture proof.

The finished shells are packed in wooden boxes, with no precaution as to jar or shock. The powder is also sold as a free-running powder, put up in water-proof bags.

"Spontaneous combustion is not possible. There is no instance known of a nitro-substitution compound, such as these, undergoing spontaneous decomposition; though the first of these bodies was discovered in 1788, and they have since been largely used in the arts."

Picric acid is $C_6 H_2 (N O_2)_3 O H$,
Sodium nitrate is $Na N O_3$,
Nitro-naphthalene is $C_{10} H_7 N O_2$.

The action of this material, taken together with its insensitiveness, would seem to indicate that it detonates rather more slowly than dynamite, and, if this may be said of any detonation, progressively.

The writer has considered this material in comparison with other high-power explosives in use, viewed in the light of the following considerations:

Any high explosive belongs to one of two general classes:

(1)—Explosives proper, which may be considered as represented by the "mixtures," such as gunpowder and the chlorate mixtures; and

(2)—Detonating "compounds," including the nitric derivatives, guncotton and nitro-glycerine, and the nitro-substitution compounds, such as Joveite, Masurite, Lyddite, Bellite, Securite, the Volney powders, Emmensite, Gelbite and Roburite. The line of demarkation between an explosion and a detonation is by no means absolutely defined in all cases, but, on the other hand, there are numbers of cases which are undoubtedly on one side or the other of this line. Black gunpowder, for example, is readily exploded when confined by heat properly applied in the form of a spark. It is exceedingly difficult to detonate, however, without the admixture of a high explosive to give it sudden and great pressure. Iodide of nitrogen is readily detonated by a fly walking on it, but it is questionable whether it has actually been exploded progressively.

In the case of gunpowder, the explosion is the result of combustion instituted and propagated by a high temperature, in other words, heat. The cause of detonation is not quite so clear. Abel's theory of "Sympathetic Explosion" was that it was due to synchronous vibrations, the originating cause of the detonation being the synchronism between the vibrations produced by the body which provokes the detonation and those which the first body would produce in detonating. Mr. Eissler, in his work on "The Modern High Explosives," states that:

"The propagation of explosions by influence is not made in virtue of an undulatory movement, which is a complex motion of a chemical and physical order in the midst of the explosive substance which is decomposed, while it is purely physical in the midst of intermediary substances which suffer no decomposition. But that which distinguishes this sort of movement of the vibrations, properly so called, is, first of all, the magnitude of the mechanical energy which it transmits; it is also the unique character of the explosive wave which is propagated in contra-distinction with the multiplicity of sonorous waves. Finally, it is essential to observe, that the explosive material does not detonate because it transmits the movement, but, on the contrary, because it arrests it, and because it transforms on the spot the mechanical energy into thermal energy, capable of suddenly raising the temperature of the substance up to the degree which will produce its decomposition."

A stick of Joveite, placed against an iron plate and fired upon with a steel-jacketed bullet from a high-powered rifle, will detonate. The impact of the bullet on the plate will generate considerable heat and at the same time set up a high order of vibration, neither of these agencies alone, as proved by the tests before mentioned, being adequate to produce that effect. The writer is informed that in the last-mentioned experiment a sheet of paper placed between the Joveite and the iron plate will nullify the effect.

The writer has concluded, then, that the statement made by the manufacturers of Joveite is correct, namely, that it requires for detonation a vibration of a certain quality and degree of intensity, together with a definite amount of heat.

The contrasted qualities of the safety explosives, as compared with dynamite, can most easily be considered by tabulating a number of the best-known characteristics of ordinary dynamite. These are as follows:

(1) Power;
(2) Cost; initial price;
(3) Rapidity of action;
(4) Facility and cost of detonation;
(5) Applicability to various conditions of work;
(6) Temperature of detonation;
(7) Freezing phenomena;
(8) Ease of transportation and cost;

(9) Ease of storage and cost;

(10) Flame from explosion;

(11) Fumes, and effects from handling;

(12) Specific gravity;

(13) Risks; divided into: (*a*) risks from proper handling; and (*b*) risks from improper handling.

There is no satisfactory way of comparing the power of different explosives from the view-point of efficiency in the rock, except by actual tests under working conditions. The ordinary method for rough comparison is to load a mortar with a known weight of explosive, and observe the distance or height to which a projectile will be thrown. Another plan is to explode a small quantity of material within a lead casket, and note the deformation of the lead. Neither of these methods gives comparable results, for the reason that the observed effect depends upon three factors: The rapidity of detonation, the volume of gases generated, and the temperature of the gases found.

The rational criterion of the strength of any explosive is, of course, the amount of energy (*i. e.* force × distance) which a unit quantity will develop. Commercially, this is of little value, because of the well-known laws of blasting. In rather hard rock which is not very seamy the higher grade of Joveite, called *3xx*, is, from all the evidences which the writer could gather, more efficient than so-called 40% dynamite. It appears to have considerably more energy, pound for pound, but does not deliver such a quick, shattering blow as the higher dynamites. When used under conditions comparable to those for 40% dynamite it should be loaded in charges corresponding with normal dynamite charges, bulk for bulk, and will then give probably more economical results. For certain kinds of tunnel work in extremely hard and tenacious rock, or where the rock is much seamed and fissured, the higher grades of dynamite are probably more efficient than the *3xx* grade of Joveite as at present manufactured.

The foregoing remarks apply, of course, only to the grades of Joveite examined by the writer. It will be noted that the highest of these grades contains only 30% of picric acid. There is every reason to suppose that it will be practicable to make a grade of Joveite, containing, perhaps, more picric acid, very much more powerful than the present product, for fused picric acid is practically Lyddite, one of the most powerful explosive substances known. Ecrasite, a salt of tri-nitro-cresol, in the same family as the picric salts, is said to be in effect twice as strong as dynamite. It is said that it is "made in Germany."

The cost of detonating Joveite is the same as that for dynamite, the same primer being used. A point which is not yet generally appreciated by workmen is that Joveite and dynamite, through improper setting, will not always detonate as they should, and, as a result, much labor and money are wasted. The point of setting the sticks in contact and, as nearly as possible, entirely filling the hole, with the maximum safe amount of tamping, is often lost sight of. In the tamping, Joveite has a great advantage, as it may be tamped heavily.

The range of practicable application for the "safety explosives" is large. The writer is informed that Joveite has been used successfully to break up frozen iron ore on the cars, an application probably quite beyond the reach of dynamite.

It may be transported long distances readily, and used for such purposes as digging post-holes in frozen ground. It should not be difficult to apply it to the driving of piles, the loosening of frozen earth and similar work.

The cost of transportation and storage of the safety explosives should be much less than with dynamite. In a railway collision, Joveite will presumably, at the most, burn up. In storage or transportation it is difficult to see where it is more dangerous than celluloid, except when adjacent to a box of fulminate caps.

The safety explosives may or may not be flameless, but the same thing is true of "carbo-dynamite" containing nitro-glycerine and charcoal.

The gases from the combustion of the picric acid compounds seem to be highly corrosive to iron and steel.

The following is a list of some of the dangers arising from the use of dynamite, which have been subdivided into two classes, and which, in the light of the facts outlined, point a striking moral:

(*a*) Dangers inevitable, even with reasonable care;
  (1) Spontaneous explosion in storage;
  (2) Lightning;
  (3) Part of charge failing to go off and remaining undiscovered until exploded either by the sun's rays or by being struck by a tool;

(4) Train wreck;
(5) Drilling near missed hole;
(6) Flame. Fire-damp.

(*b*) Dangers incidental to the handling of dynamite as practiced every day;

(1) Dropping stick or box;
(2) Hole too small for cartridge; ramming down cartridge;
(3) Ramming too hard, or ramming with metal bar;
(4) Deepening missed hole;
(5) Returning to relight fuse;
(6) Testing the end of a hole with an iron bar after a blast, to see if any of the charge remains;
(7) Forcing primer into cartridge;
(8) Ramming in the first ball of tamping clay;
(9) Breaking a cartridge when near the freezing point;
(10) Stepping upon particles of explosive;
(11) Thawing in tin over a fire;
(12) Thawing in front of kitchen fire;
(13) Thawing in the men's boots or shirts;
(14) Thawing in an oven;
(15) Hot water containing dynamite placed on a blacksmith's fire;
(16) Thawing with candle;
(17) Reheating water which has been used in thawer;
(18) Throwing on ground water which contains nitro-glycerine from thawing cartridges;
(19) Rubbing cartridge in hands to complete thawing;
(20) Cartridge left in pocket of garment hung before fire to dry;
(21) Having cartridge and primer near each other when not in use;
(22) Destroying material not considered desirable.

Numbers (2) and (6) are the only cases under Class (*a*) in which danger is to be apprehended from the use of Joveite. The experiment of passing a high-tension spark through it is perhaps as near to natural conditions as it is practicable to get in the laboratory, but the writer is not satisfied that Joveite may not be exploded by lightning.

Under Class (*b*) we have (5) and (21) as the only elements of danger mentioned above which are common to dynamite and Joveite.

This list of "dangers" which the writer has complied is, of course, not complete, but it should be pretty well distributed over the field of ordinary engineering practice.

A rival product to Joveite, previously mentioned, is Masurite, which the writer has not tested personally. It resembles Joveite, and is claimed, doubtless with justice, to be very insensitive to shock, heat, percussion, concussion, an electric spark, etc. The composition is secret, but it contains a large amount of ammonium nitrate. It is claimed to be about as strong, bulk for bulk, as dynamite of corresponding grade, and to be not only flameless but non-inflammable. The cartridge is of paper, as at present made, and is probably subject to the same objections as the early Joveite cartridges before the adoption of cloth fiber. It will not detonate properly when wet, and requires a double-strength primer. An important objection to it is in the fact that the material cakes, and in that condition will not detonate readily, but when being loaded, the cartridges must be thoroughly rolled between the hands. With reference to the claim that this material is non-inflammable, the point suggests itself whether in a large fire, accompanied with much smoke and carbon in suspension, ammonium nitrate would not form a highly explosive mixture. This point the writer will not attempt to discuss.

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PAPERS AND DISCUSSIONS.

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AN EXPERIMENTAL STUDY OF THE RESISTANCES TO THE FLOW OF WATER IN PIPES.

By Augustus V. Saph, Assoc. Am. Soc. C. E., and Ernest W. Schoder, Jun. Am. Soc. C. E.

To be Presented September 2d, 1903.

Before proceeding to the presentation and discussion of the experimental data upon which this paper is based, it may be of interest to describe briefly the reasons which have led the writers to make the treatment as broad as the title indicates.

As graduate students in Cornell University, the writers had been associated in experimental hydraulics for a year and a half before the investigations to be described were begun. During that time they had experienced a number of surprises in an investigation on the effect of curvature on the flow of water in pipes,* and the necessity of refraining from jumping at conclusions, with little or no experimental evidence, had impressed them more and more as the work advanced.

In 1900, Gardner S. Williams, M. Am. Soc. C. E., Engineer in Charge of the Hydraulic Laboratory of Cornell University, made

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* *Transactions*, Am. Soc. C. E., Vol. XLVII, p. 295.

an investigation,* from which one of the most interesting conclusions drawn was that the power of the velocity, with which the loss of head in water pipes varies, is dependent on the diameter of the pipe, being about 1 for very small tubes and increasing to about 2 for large pipes such as used ordinarily in the practice of the civil engineer.

For pipes below ½ in. in diameter, the value seemed to drop rapidly, while for pipes above that diameter the plotting showed a very gradual rise. However, the experimental results in the region where the most rapid change in the power seemed to occur were too few to give that feeling of entire confidence which is evident in the case of most of the commonly accepted laws of Nature. The desirability of further evidence was first pointed out to the writers by Professor Williams, and it is due to his interest in the matter, and to the true university spirit displayed by the College of Civil Engineering of Cornell University, that the writers were enabled to undertake experiments which, whatever their final aim became, had, as their primary object, the determination of the law governing the flow of water in small pipes.

The writers entered upon the investigation with the feeling that the small sizes of the pipes to be experimented upon would in no respect vitiate the results, from an engineering point of view. As will be shown later, the nature of the apparatus and the method of experimentation were to be such as to secure a high degree of accuracy in all the measurements. The writers, in their studies on the effect of curvature, had reached the conclusion that, in the manner of flow, there is practically no difference between a 2-in. and a 30-in. pipe. They expected, therefore, that much might be learned from the results of a comprehensive set of experiments on small pipes.

In addition to whatever light might be thrown upon the general subject of the flow of water in pipes, as ordinarily understood, the writers saw here an excellent opportunity to pursue their studies on the effect of the temperature of the water upon the loss of head, and hence upon the discharging capacity of pipes. The accepted idea in this matter is that the effect is negligible in pipes of commercial size. The writers had been led to question this, from their work on a 2-in. pipe,† and they saw in the experiments to be described a means of forming an idea concerning, or even of predicting the effect in large pipes.

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* *Journal* of the Association of Engineering Societies, Vol. XXVI (Mar., 1901), p. 135.

† *Transactions*, Am. Soc. C. E., Vol. XLVII, p. 818.

Soon after beginning the experiments it was found that the power of the velocity, with which the loss of head varies, remains almost constant for the fifteen pipes of different sizes, but all of the same material (seamless-drawn brass); or, in the formula,

$$H = mV^n,$$

where H is the loss of head and V the mean velocity of the water in the pipe, the value of n was found to remain nearly constant for all the pipes. This somewhat astonishing fact appeared at first to be irreconcilable with the results of the investigation by Professor Williams; but, fortunately, the writers' experiments covered a considerable range of velocities, and it was soon found that the group of experiments on small brass and glass pipes (by Jacobson), upon the indications of which Professor Williams, with considerable justification, had placed great confidence, were all made with velocities below the "critical velocity," in which region the value of n is about 1. Hence the results were not comparable with results of experiments made under ordinary, or "above critical velocity," flow. This phenomenon will be discussed more fully later.

The fact that the value of the exponent of V was found to be almost constant for pipes ranging from $\frac{1}{10}$ in. to 2 ins. in diameter would have been sufficient of itself to warrant an investigation into the indications of reliable experiments on large, smooth pipes; for the smallest of these sizes bears the same relation to the largest as a 2-in. pipe bears to a 40-in. main (see Fig. 1, Plate XXXVII). If this were the only argument for entering on such a study, the writers feel that they would well deserve the flood of criticism which is ever threatening those venturous persons who presume to affirm that the same laws of Nature control the flow of water in the smallest pipes in the laboratory and in the largest supply mains running over hill and dale. In this paper it is aimed to present a few additional arguments which may serve to make such an affirmation appear a little less ridiculous than heretofore.

After the experiments had progressed far enough, and several different temperatures of water had been experimented upon for each of the pipes, it became evident that there is nothing to support the notion that the effect of temperature is negligible in large, smooth pipes. In fact, the indications were found to point to such a considerable effect on pipes of large size that the limits of error which most hydraulic engineers would assign to the best formulas in use (all of which neglect temperature effect) are exceeded several times over, owing to the temperature factor alone.

The results of the brass-pipe experiments showed such harmonious relations that the writers were led to undertake some experiments on pipes which were less ideal and more practical. For this purpose five galvanized-iron pipes, ranging from ½ in. to 1 in., commercial sizes, were chosen. While these experiments were conducted with the same care and precision as those on the brass pipes, and while each pipe by itself gave a consistent set of results, yet, between these results for the different pipes, there was a surprising lack of harmony, if it be assumed that all pipes were of the same degree of roughness. In short, the value of n, the exponent of V, in the formula $H = m\ V^n$, was found to vary so much for pipes nominally and apparently of the same kind that the writers saw here a consideration which might throw considerable light on the vagaries of the much-discussed, recorded pipe-experiments of modern and ancient times.

It may be well at this point to give a few reasons why the formula $H = m\ V^n$ is used. In the first place, the very fact that in the Chezy formula, $V = C\sqrt{r\ s}$, or, in the familiar textbook formula,

$$H = 4 f \frac{l}{d} \frac{V^2}{2 g},$$

the values of C and f are different for different velocities, shows that the power is something other than 2, if there is, indeed, any exponential law which is applicable.* And the writers venture to say that, up to the present time, there has not been evolved any theory which will assist in answering this question.

To be sure, there seems to be a more or less firmly grounded notion among some hydraulicians that the laws of gravity decree that the hydraulic slope or the loss of head must vary as the square of the velocity. The fallacy of this has been shown very clearly by Professor I. P. Church,† Assoc. Am. Soc. C. E., who emphasizes the fact that the question concerns primarily the relation between the velocity and the resistances, or "friction," and through this, as an entirely dependent matter, the relation between the velocity and the hydraulic slope. An illustration may make the point clearer. It is quite possible, by the use of compressed air, to maintain a high velocity in a very long pipe laid on an absolutely level grade with just enough head of water at the entry to keep the pipe full. Now, it is at once apparent that the law of a falling body has nothing to do with the relation existing between the pressure in the compressed-air chamber and the velocity of the water in the pipe. In fact, the force of gravity alone, in this case, would cause no flow at all.

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* See discussion by Allen Hazen, M. Am. Soc. C. E., in *Journal* of the Association of Engineering Societies, Vol. XXVI (1901), p. 168.

† In *Engineering News*, Vol. XLVI, p. 382.

In the absence of any theory, the only thing to do is to study the indications of experiments of known accuracy. These should embrace a wide range of velocities and several different degrees of roughness. The records of many such experiments have been before the engineer for a number of years, as have been also the records of investigations dealing with the question of exponents other than 2 for the velocity, or other than $\frac{1}{2}$ for the slope and the diameter (or the hydraulic radius). Unfortunately, the formulas with fractional exponents, which have been proposed from time to time, have been regarded generally as approximations, little, if any, closer to the truth than the standard Chezy formula, and far less easy to apply. In fact, some engineers have been led to question whether or not water flows in a pipe according to any definite determinable laws whatsoever.

Now, the writers have investigated, by the method of logarithmic plotting of the observed losses of head with the corresponding velocities, experiments in which the velocity ranges from a fraction of a foot per second up to 44 ft. per second. Their own experiments, almost 800 in number, and including twenty-three kinds of pipe and hose, cover a range of velocity from $\frac{1}{10}$ ft. per second to 22 ft. per second. In all these experiments, and especially in those of known accuracy in all measurements, the logarithmic plottings yield straight lines. The slopes of these lines differ considerably among themselves, or, in other words, the losses of head vary as various powers of the velocities,* but, whatever the slope of the line, each pipe appears to have a definite law, expressible in the form,

$$H = m\,V^n.$$

The values of m and n are constant for a given pipe in a given condition for all velocities. The "coefficient of roughness" is entirely provided for by them. These appear to be scientific facts, and the writers felt that they had no choice as regards the formula to be used. As has been stated already, there is no existing theory which is applicable; but the experimental evidence is quite conclusive.

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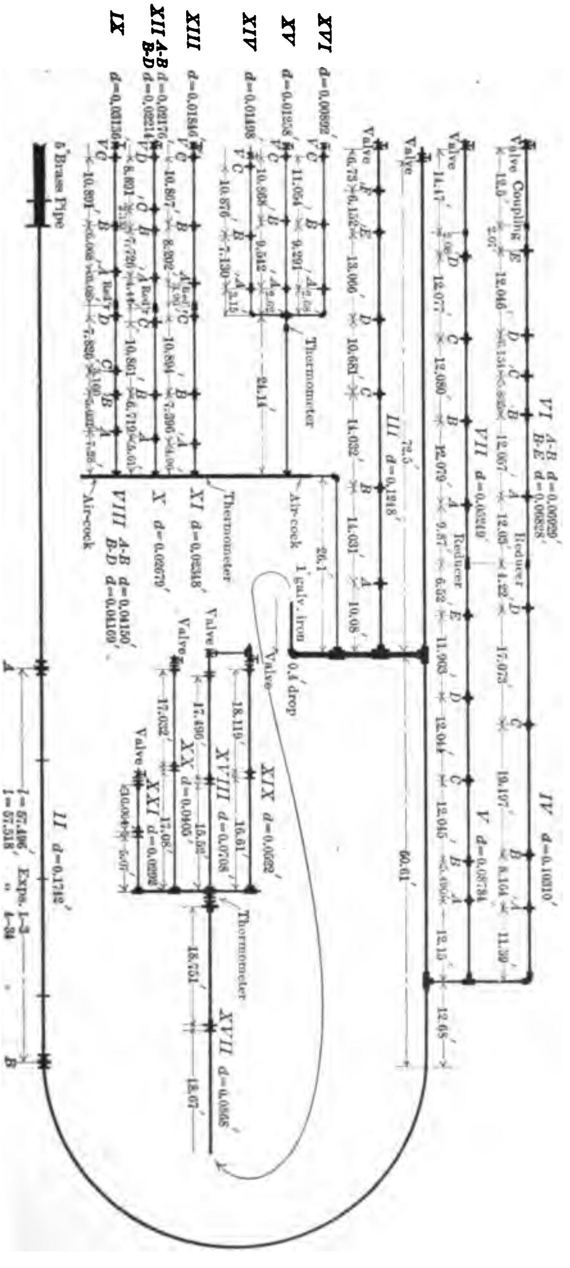
* *Transactions*, Am. Soc. C. E., Vol. XLIX. p. 145.

It must not be inferred, from what has been stated, that the writers are opposed to the Chezy and like formulas, or, on the other hand, that they uphold the forms with fractional exponents for practical uses; but, for purposes of investigation, it would be most irrational to start with a formula which is known to be only an approximation, especially when the exact formula is just as easy to treat. But, after such an investigation is completed, on the actual showings of the experiments, it will be easy and quite proper to look for approximate forms which may be more convenient for the engineer to use. On this point, however, more can be said, and to better purpose, after the presentation of the experimental evidence.

Enough has been stated to indicate that the scope of the investigation, as planned originally, has been enlarged considerably, and for such reasons that the writers feel that the whole subject of the flow of water in pipes may be considered open for a treatment in which the aim is to present the facts, in their relations to one another, in a thoroughly rational and comprehensive manner. It is the purpose, as far as possible, to make all plottings bird's-eye views of the whole subject, so that the experimental results may show at a glance the probable laws which too often have been obscured by misleading approximate formulas, and unfortunate attempts to make the results of the roughest kind of measurements fit these formulas. In the general plotting, many results of such rough measurements have been included. In fact, the idea has been to consider all experiments which are on record in any recognized source of information. But it is believed that the method of plotting has reduced to the greatest possible extent the question of individual judgment, and has allowed each experimental result to have its merited influence in controlling the final conclusions.

DESCRIPTION OF APPARATUS.

The general plan of the pipe system experimented upon is shown in Fig. 1. The pipes were located in the basement of Lincoln Hall, the principal building of the College of Civil Engineering, Cornell



PLAN OF PIPE SYSTEM.
(SCALE DISTORTED.)

FIG. 1.

University. The system was fed through the 5 and 2-in. pipes. The former extended from an equalizing cylinder, which could be supplied either from a tank in the attic (the supply to which was controlled by a float-valve) or directly from the campus mains.* The pressures in the cylinder, under static conditions, were approximately 20 and 30 lbs. from the attic tank and the main, respectively.

All elbows, tees and auxiliary pipes are of galvanized iron except the plain iron steam-pipe header from which extend Pipes *VIII* to *XIII* and a pipe feeding Pipes *XIV*, *XV* and *XVI*. All piezometric fittings are of brass. Experimental Pipes *II* to *XVI* are of seamless-drawn brass, and Pipes *XVII* to *XXI* are of ordinary commercial, galvanized-iron stock. The fittings on all the pipes except Pipe *II*† are described herein.

Piezometric Fittings.—The individual pipe lengths of Pipes *III* to *XVI* are connected by piezometric couplings of special design. Each coupling is in two pieces which screw together in such a way that when the pipe is ready for experimentation the pressure is transmitted to an annular chamber through a continuous slit or break in the pipe $\frac{1}{100}$ in. wide. The details of the construction are shown in Fig. 2, and in Fig. 1 of Plate XXXVII. The latter is from a photograph of piezometric couplings on Pipe *III* and Pipe *XVI*, and shows also the comparative sizes of these two pipes. The lathe work inside these couplings is practically perfect, while the differences between the inside diameters of the pipe and the coupling where the faced end of the pipe screws up against a shoulder are generally not more

SECTION OF PIEZOMETER NO. *III F*

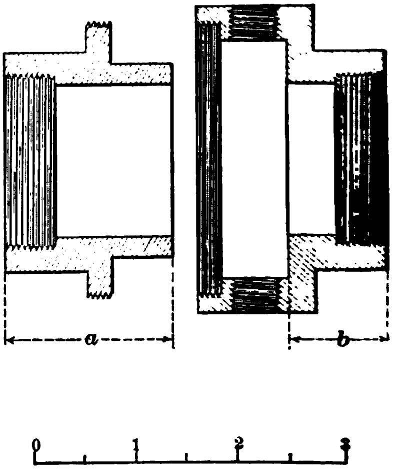


Fig. 2.

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* The cylinder and the controlling valves are shown in Fig. 119, *Transactions*, Am. Soc. C. E., Vol. XLVII, p. 297. The cycloidal mouthpieces between the cylinder and the 5-in. pipe and between the latter and the 2-in. pipe are described on p. 20 of the above-mentioned volume, and also on p. 180 of the *Journal* of the Association of Engineering Societies, Vol. XXVI, 1901, while Plate 25 in the latter gives a longitudinal section of this part of the apparatus.

† The piezometer fittings on Pipe *II* have been illustrated on p. 17 and in Plate IX, Fig. 1, *Transactions*, Am. Soc. C. E., Vol. XLVII.

PLATE XXXVII.
PAPERS, AM. SOC. C. E.
MAY, 1903.
SAPH AND SCHODER
ON FLOW OF WATER IN PIPES.

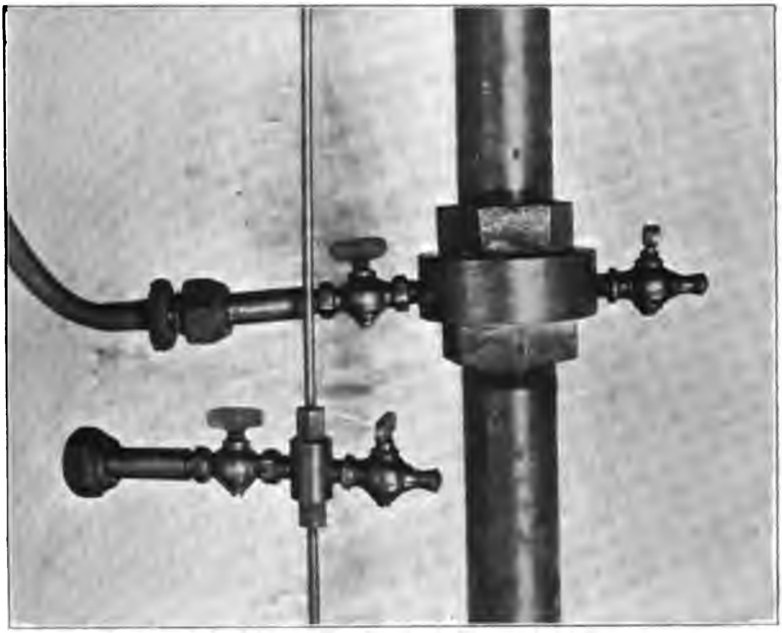

FIG. 1.—PIEZOMETER COUPLINGS. PIPES *III* AND *XVI*.

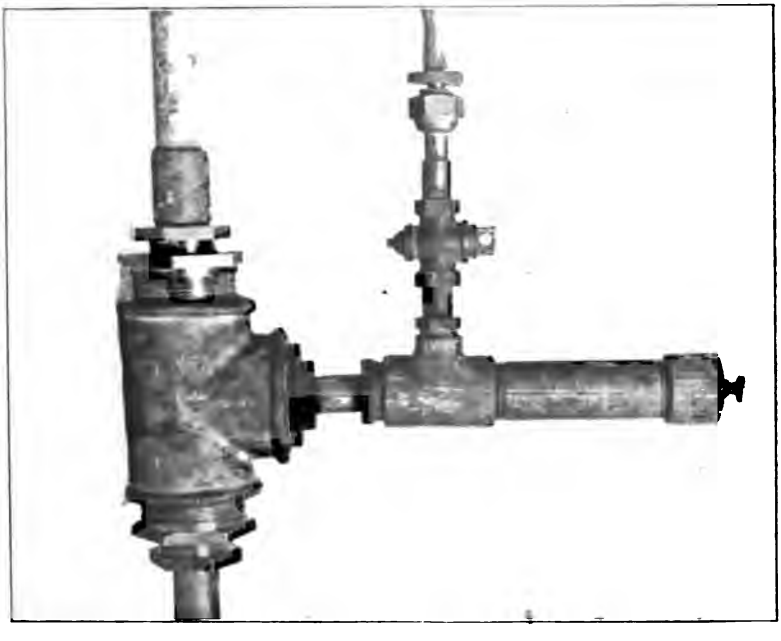

FIG. 2.—PIEZOMETER CHAMBER ON PIPE *XVIII*.

than $\frac{1}{1000}$ in., or the smallest amount which can be measured accurately with the ordinary micrometer calipers (see Table No. 1). Before the couplings were turned, the ends of all the pipes had been measured and the pipes matched. All threads were lathe-cut. In general, the pipes, when set up, left nothing to be desired, as far as nearly ideal conditions are concerned. The writers feel that without the excellent machine-work done by Mr. C. D. Cass, Mechanician to the Hydraulic Laboratory, the value of the experimental accuracy would have been very small. They desire to acknowledge their indebtedness to Mr. Cass for his accurate and conscientious work.

On account of the roughness of the galvanized pipes, as well as on account of the variable diameter, it was deemed best to avoid any form of joint at the point where the pressure was to be taken off. Accordingly, four $\frac{1}{8}$-in. holes, 90° apart, were drilled through the pipe walls $3\frac{1}{2}$ ins. from the ends of each experimental length. For the two smallest pipes the holes were $\frac{3}{32}$ in. in diameter, and the distance from the ends was $2\frac{1}{2}$ ins. The drill passed through both walls of the pipe at one setting. Thus, only two of the four holes had any burr inside. This was removed carefully with a rounded file. These holes in the finished piezometer fitting communicated to a chamber formed by a large tee slipped over the pipe and provided with a pair of brass bushings at each end. Between these bushings, and on the pipe, some candle wicking soaked with tallow was wound. When the smaller bushings were screwed up, the fitting was water-tight. A photograph of one of these fittings on Pipe *XVIII* ($\frac{3}{4}$-in. galvanized iron) is shown in Fig. 2, Plate XXXVII.* In order to avoid any error due to unequal diameters at the piezometers, all the experimental lengths were turned end for end, after the first set of experiments had been completed, and a second series was run with the reversed arrangement. In this way, also, the effect of any slight differences in the conditions of the flow at the two piezometers was eliminated. The up-stream, or entry, length of pipe was connected to the experimental length by an ordinary coupling. The ends of the pipe, however, were faced, and the threads were cut so that a butt joint was secured, avoiding the disturbing effect of the usual coupling on wrought-iron pipe where the ends do not come together.

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* The air-chamber has a section like that shown on p. 17, *Transactions*, Am. Soc. C. E., Vol. XLVII.

TABLE No. 1.—DIAMETERS (IN INCHES) OF BRASS PIPES AND PIEZOMETERS.

No. of Pipe.	Length No. 1.	Piezometer A.	Length No. 2.	Piezometer B.	Length No. 3.	Piezometer C.	Length No. 4.	Piezometer D.	Length No. 5.	Piezometer E.	Length No. 6.	Piezometer F.	Length No. 7.
III............	1.4976 1.4986	1.498	1.4984 1.4976	1.498	1.4986 1.4988	1.498	1.4979 1.4982	1.498	1.4978 1.4984	1.498	1.4960 1.4988	1.498	1.4988 1.4980
IV............	1.2465 1.2463	1.246	1.2376 1.2378	1.237	1.2361 1.2368	1.237	1.2378 1.2362	1.237	1.2378 1.2384	....	....	....	....
V............	1.0698 1.0696	1.069	1.0531 1.0541	1.054	1.0543 1.0543	1.054	1.0539 1.0557	1.054	1.0539 1.0558	1.054	1.0531 1.0530	....	....
VI............	0.8321 0.8310	0.8315	0.8313 0.8318	0.8315	0.8197 0.8201	0.819	0.8201* 0.8201	0.819	0.8191 0.8189	0.819	0.8189 0.8344	....	....
VII............	0.6307* 0.6303	0.630	0.6297 0.6293	0.630	0.6298 0.6299	0.630	0.6303 0.6305	0.630	0.6307 0.6301	....	....	....	....
VIII............	0.4976* 0.4982	0.498	0.4982 0.4977	0.498	0.5008 0.5006	0.500	0.5008 0.4998	0.500	0.5006 0.5008	....	....	....	....
IX............	0.3764 0.3766	0.376	0.3763 0.3762	0.376	0.3750 0.3766	0.376	0.3766 0.3768	....	....	....	....	....	....
X............	0.3207 0.3218	0.3215	0.3218 0.3221	0.3215	0.3215 0.3217	0.3215	0.3217 0.3218	....	....	....	....	....	....
XI............	0.2817 0.2817	0.282	0.2813 0.2823	0.282	0.2821 0.2811	0.282	0.2811 0.2818	....	....	....	....	....	....
XII............	0.2608 0.2613	0.261	0.2622* 0.2602	0.261	0.2652 0.2644	0.266	0.2652* 0.2654	0.266	0.2644 0.2661	....	....	....	....
XIII............	0.2217 0.2209	0.222	0.2218 0.2220	0.222	0.2217* 0.2220	0.222	0.2217 0.2211	....	....	....	....	....	....
XIV............	0.1807 0.1789	0.180	0.1801 0.1801	0.180	0.1800 0.1799	0.180	0.1799 0.1787	....	....	....	....	....	....
XV............	0.1507 0.1492	0.151	0.1511 0.1523	0.151	0.1506 0.1526	0.151	0.1526 0.1514	....	....	....	....	....	....
XVI............	0.1057 0.1081	0.107	0.1071 0.1083	0.107	0.1055 0.1073	0.107	0.1073 0.1081	....	....	....	....	....	....

NOTE.—The first of the two diameters under each length is for the up-stream end in the usual arrangement. This is also the marked end, except where an asterisk denotes that the unmarked end is up stream.

Measurements of Diameters.—From the ends of all the brass and galvanized-iron pipes there were cut sample rings from ⅛ to ¼ in. long. Before cutting off the rings in the lathe, the ends of the pipe were faced, the tool being started on the inside wall of the pipe, thus securing a sharp, clearly defined edge, and avoiding entirely the burr which would result if the tool were started on the outside.

Four diameters were measured on each ring. The rings from the brass pipes were placed on the bed of a dividing engine, and readings were taken as the inner edges appeared under the cross-hair of the microscope. The bed advanced 1 mm. for each turn of the screw, and one two-hundredth part of a turn could be read directly from a graduated disc on the screw. The rings from the galvanized pipes were measured with small micrometer beam-calipers reading to one-thousandth of an inch.

The means of the four measured diameters on each ring, corresponding to the mean diameters of the ends of the brass pipes, are given in Table No. 1. The numbers refer to the position of the individual pipe lengths in the experimental arrangement, the lengths being numbered consecutively, beginning at the up-stream end. In a number of cases a single piece of pipe was cut into two or three lengths. Hence the question as to the uniformity of diameter can be answered by direct evidence. The following list shows what lengths were cut from the single factory lengths.

III.—No. 7 was cut from No. 6
IV.— " 5 " " " " 2
V.— " 2 " " " " 5
VI.— " 4 " " " " 3
VI.— " 6 " " " a piece, the remainder of which was not used.
VII.—No. 5 was cut from No. 1
VIII.— " 2 " " " " 1
VIII.— " 5 " " " " 4
VIII.— " 3 " " " " 4
IX.— " 1 " " " " 2
IX.— " 4 " " " " 3
X.— " 1 " " " " 2
X.— " 4 " " " " 3
XI.— " 1 " " " " 2

XI.—	No.	5	was	cut	from	No. 4
XI.—	"	3	"	"	"	" 4
XII. —	"	1	"	"	"	" 2
XIII.—	"	1	"	"	"	" 2
XIII.—	"	4	"	"	"	" 3
XIV.—	"	1	"	"	"	" 2
XIV.—	"	4	"	"	"	" 3
XV.—	"	1	"	"	"	" 2
XV.—	"	4	"	"	"	" 3
XVI.—	"	1	"	"	"	" 2
XVI.—	"	4	"	"	"	" 3

If a pipe was cut into three pieces, the shortest piece was cut off first. All pieces were cut from the unmarked end of the factory length. The unmarked end of the original pipe became the unmarked end of the first piece cut off. Hence, the marked end of a short pipe cut from a factory length represents a section in the middle of the latter.

TABLE No. 2.—DIMENSIONS OF GALVANIZED PIPES.

No. of pipe.	Length, in feet.	DIAMETERS, IN INCHES.					
				BY CALIPERS.			
		Nominal.	Standard.	Marked end.	Unmarked end.	Water-filling method.	Accepted diameter.
XVII.............	18.751	1-in.	1.048	1.046 1.050*	1.037 1.044	1.031 1.037	1.036 1.042†
XVIII............	17.496	¾-in.	0.824	0.789 0.850	0.799 0.850	0.815 0.849	0.805 0.850†
XIX..............	18.119	½-in.	0.623	0.627 0.631*	0.628 0.631	0.627 0.623	0.627 0.626†
XX...............	17.032	⅜-in.	0.494	0.498 0.489	0.502 0.482	....	0.496 0.486†
XXI..............	10.064	¼-in.	0.364	0.363 0.355*	0.345 0.345	....	0.354 0.350†

NOTE.—The lengths given in the table are for the experimental sections. For other lengths see Fig. 1.

* The marked ends are also the up-stream ends in the first or unreversed arrangement, except where an asterisk denotes the opposite.

† The experimental section.

In Table No. 2 are given the mean diameters of the galvanized pipes. In addition to the end caliperings, Pipes *XVII*, *XVIII* and *XIX* were measured by the water-filling method, special precautions being taken to avoid the adhesion of air to the walls of the pipe. The pipe was held vertically, and a stiff wire with a piece of cloth tied to the lower end was inserted until the cloth was near the bottom of the pipe. The pipe was then filled, and the wire was drawn up with a rotary motion. The pipe was finally filled flush, and the contained water was caught and weighed to the nearest $\frac{1}{100}$ lb. Each pipe length was filled three times. Allowance was made for the small quantity of water which remained adhering to the inside walls of the pipe, a determination having been made.

Measurements of Lengths.—All lengths were measured with an accurate steel tape, and were checked by independent measurements. They are given in Fig. 1 and in Table No. 3. For the experimental sections, they are, in all cases, between the piezometric slits for the brass pipes, and between the piezometric holes for the galvanized pipes.

Methods of Experimentation.—All pipes were laid straight, and, where necessary, intermediate supports were used between the hangers on which the whole pipe system was supported. On account of their very small sizes, Pipes *XIV*, *XV* and *XVI* were laid on a board, and held straight by tacks. The hangers were levelled up carefully.

As shown in Fig. 1, there are fourteen valves to control the flow in the various experimental lines, several of which have two different sizes of pipes. It will be noticed that there is in all cases a considerable length of pipe up stream from the first piezometer, or Piezometer *A*. In fact, the writers had agreed that it is desirable to have an entry length of approximately two hundred diameters, in order to allow the flow to become normal. While this allowance is ample, it does not appear to be excessive. A length of one hundred diameters is, in the writers' opinion, hardly enough to allow the disturbances due to a curve at entry to die down fully.*

In order to get as large a range of velocities as possible, the downstream sections of Pipes *VIII* to *XVI* were removed and replaced again from time to time. On several occasions Pipes *VI*, *VII*, *IX*, *XII* and *XIII* were entirely removed, in order to increase the discharge of the larger pipes ordinarily feeding into them.

***Transactions*, Am. Soc. C. E., Vol. XLVII, p. 317.

TABLE No. 3.—BRASS PIPE—LENGTHS OF SECTIONS AND DIAMETERS.—SEE FIG. 1.

Pipe.	Section.	Length, in feet.	Accepted diameter, in feet.	Pipe.	Section.	Length, in feet.	Accepted diameter, in feet.
II.	*A-B*	57.496	0.1742	*IX.*—1	Reducer-*A*	6.08	0.08137
		57.518		2	*A-B*	6.068	
III.—1	Entry-*A*	10.08	0.12484	3	*B-C*	10.891	
2	*A-B*	14.031		4	*C*-Valve.	1.02	
3	*B-C*	14.032		*X.*—1	Entry-*A*	5.61	0.06659
4	*C-D*	10.681		2	*A-B*	6.719	
5	*D-E*	13.066		3	*B-C*	10.861	
6	*E-F*	6.152		4	*C*-Reducer.	1.075	
7	*F*-Valve.	6.73		*XI.*—1	Entry-*A*	4.96	0.05967
IV.—1	Entry-*A*	11.39	0.10387	2	*A-B*	7.396	
2	*A-B*	8.164	0.10311	3	*B-C*	10.894	
3	*B-C*	19.197		4	*C*-Reducer.	1.06	
4	*C-D*	17.073		*XII.*—1	Reducer-*A*	4.44	0.02176
5	*D*-Valve.	4.23		2	*A-B*	7.723	
V.—1	Entry-*A*	12.15	0.08906	3	*B-C*	2.133	0.02209
2	*A-B*	5.490	0.08785	4	*C-D*	8.891	
3	*B-C*	12.045		5	*D*-Valve.	1.04	
4	*C-D*	12.044		*XIII.*—1	Reducer-*A*	3.90	0.01346
5	*D-E*	11.903		2	*A-B*	8.202	
6	*E*-Reducer.	6.52		3	*B-C*	10.867	
VI.—1	Reducer-*A*	12.03	0.06930	4	*C*-Valve.	1.02	
2	*A-B*	12.057		*XIV.*—1	Entry-*A*	3.15	0.01496
3	*B-C*	5.835	0.06831	2	*A-B*	7.130	
4	*C-D*	6.134		3	*B-C*	10.876	
5	*D-E*	12.046		4	*C*-Valve.	1.03	
6	*E*-Coupling.	2.07	0.06889	*XV.*—1	Entry-*A*	2.62	0.01231
VII.—1	Reducer-*A*	9.87	0.05251	2	*A-B*	9.542	
2	*A-B*	12.079		3	*B-C*	10.868	
3	*B-C*	12.080		4	*C*-Valve.	1.03	
4	*C-D*	12.077		*XVI.*—1	Entry-*A*	2.68	0.00986
5	*D*-Enlargement	2.08		2	*A-B*	9.291	
	to valve.	14.47	....	3	*B-C*	11.054	
VIII.—1	Entry-*A*	7.28	0.04149	4	*C*-Valve.	1.02	
2	*A-B*	5.031		....	....	....	....
3	*B-C*	3.160	0.04172	....	....	....	....
4	*C-D*	7.826		....	....	....	....
5	*D*-Reducer.	1.060		....	....	....	....

The differences of pressure between the piezometers were measured by either mercury or water gauges, of the differential type, the pressures being transmitted from the piezometers to the gauge columns by heavy, three-ply, cotton-insertion, rubber tubing. The scales of these gauges are divided into double centimeters and tenths, the hundredths being estimated. All gauges were supplied with riders to facilitate accurate reading of the menisci. The mercury gauges had three columns, and the water gauges had either two or three columns. Any of the gauges could be used as two-column gauges, if desired.

The water was discharged for measured intervals of time into a tank on one of three platform scales. One of these scales has a capacity of 2 500 lbs., and is accurate to the nearest pound. Another has a capacity of 350 lbs., and is accurate to $\frac{1}{10}$ lb. The third is sensitive to $\frac{1}{100}$ lb. for weights not exceeding 50 lbs. The two smaller scales were calibrated with standard weights in the possession of the College of Civil Engineering. The largest was tested by comparison.

Thus, it was possible to secure the desired accuracy for the measurement of the discharge of the smallest of the pipes as well as the largest. In general, the attempt was made to secure an average accuracy of 1 in 500 in all measurements, whether of weight, time or gauge differences. For the highest velocities, a much greater accuracy has been obtained, while for some of the very lowest velocities, the weight or gauge difference was so small as to render the result accurate within only about $\frac{1}{2}$ of 1%, or, very rarely, within only 1%; but, for the vast majority of the experiments, it is believed that the attempted accuracy has been secured.

For many of the first experiments, the time was taken from a record sheet of a chronograph connected to the diverting arrangements and to the standard clock of the Astronomical Laboratory. It was found that the error in using an ordinary well-regulated watch was in general only a small fraction of a second. In fact, by using a small reading glass, the $\frac{1}{5}$-second beats can be seen quite distinctly on the second hand of the ordinary watch. Hence, for all the later runs, the time was taken with an ordinary watch, and it is believed that the time element is well within the attempted limit of accuracy.

During the time in which the flow was being measured, the gauge was read from six to twenty times. When the pressure was taken from the attic tank the columns were quite steady, but when connected to the campus mains, there was considerable vibration, yet not enough to impair greatly the accuracy of the readings. The main pressure was used, generally, only for the highest velocities, and hence the greatest gauge differences. The gauges were tested under no-flow conditions before and after, and frequently during, every series of runs. In general, no trouble was experienced. The columns came quickly to a common level. This condition of affairs the writers attribute to the complete control of the apparatus, the excellence of hose and gauge connections, and the great care taken to free the whole pipe system from air before starting any experiment. The temperature of the water for the first experiments was taken in the tank after the runs.

For these cases the temperature of the water was within 1 or 2° Fahr., of the temperature of the room. For the later experiments on Pipes *VIII* to *XVI*, and for all the experiments on Pipes *XVII* to *XXI* (of galvanized iron), the temperature was taken with a thermometer inserted in a stuffing-box, and with its bulb well within the pipe. The positions of these thermometer stuffing-boxes are shown in Fig. 1. The temperature was taken at the beginning and at the end of each experiment, and the mean value used, the differences being small. For Pipes *II* to *VII* it was found that the temperature in the pipes was the same as that in the tank after filling, within less than half a degree. Hence, the latter was taken, except at low velocities, when a small jar full of the water was caught just before and after each run and the temperature was read immediately.

Methods of Reduction.—In reducing weights to velocities the weights per cubic foot of distilled water at the observed temperature were taken from a table by the late Hamilton Smith, Jr., M. Am. Soc. C. E. These values are known to be correct within $\frac{1}{10}$ of 1% for the water used in the experiments.

In reducing observed heads on the differential water gauges a correction is necessary on account of the weight of a column of air of a height equal to the observed difference and under an average pressure of, approximately, 1½ atmospheres. This amounts to a subtraction of approximately one five-hundredth of the observed differences. There is another correction on account of the difference between the temperature of the water in the gauge and that in the pipe, but this is very small, and is an uncertain amount, varying from nothing to a possible subtraction of one-six-hundredth of the observed difference. The correction actually applied, to cover these two items, is a subtraction of one five-hundredth of the observed difference for temperatures in the pipe below 60° Fahr.

For reducing observations on the mercury gauges, the "water equivalent" was obtained by direct comparison. A line of levels was run, and the elevation of the top of the attic tank above the zeros of the gauges was determined accurately. One observer measured the level of the surface of the water in the tank, while another took readings on the gauges in the basement. Eight determinations were made, with as many different heights of the water surface. The "water equivalent" was found to be 13.57 for mercury and water at 71° Fahr.

The eight determinations agreed within $\frac{1}{10}$ of 1 per cent. The weight of a column of air from the gauge to the attic was included in the calculation. Since the temperature of the room, and hence the specific gravity of the mercury in the gauges, was practically constant during the course of the experiments, the observed differences were corrected according to the specific gravity of the water flowing in the pipe. Thus all heads are reduced to water at the temperature of that in the pipe.

All reductions of weights to velocities, and of observed gauge differences to loss of head, in feet of water per 100 ft. of pipe length, have been checked by independent calculations. In addition, all results have been subjected to the test of two different methods of plotting, and any apparently wild cases have been recalculated. The writers have been pleased to find that the efforts to maintain a high degree of accuracy in all measurements have borne good fruit in the resulting indications.

Table No. 4 gives the data for the brass pipes, and Table No. 5 the data for the galvanized pipes.

Brass Pipe *III*.

30	*B-D*	2.70	*D-F*	2.69	70.2°	3.095	All heads for Pipe *III* were read on water gauges except in Experiment 194 and Experiments 308 and 309 for Sections *B-D* and *D-F* together. One experiment (309*b*.) read on water gauge.
31	"	1.96	"	1.96	70	2.576	
32	"	1.29	"	1.30	69.8	2.029	
33	"	0.709	"	0.716	69.8	1.481	
34	"	0.438	"	0.423	70	1.067	
35	"	16.04	*E-F*	16.05	68.8	8.478	
36	"	11.58	"	11.58	69.1	7.060	
37	"	8.40	"	8.34	69.1	5.887	
38	"	5.96	"	5.92	69.2	4.858	
39	"	3.47	"	3.41	69.1	3.568	
202			*B-F*	0.070	71.8	0.383	
203			"	0.291	71.8	0.870	
204			"	0.140	71.7	0.571	
194	*B-D*	17.74	*D-F*	17.70	68.8	8.994	
308	"	18.83	"	18.84	62.0	9.037	
309	"	15.70	"	15.83	62.5	8.230	
309*b*	"	15.89			62.5	8.280	
310	"	11.77			62.1	7.018	
311	"	8.77			62.1	5.947	
312	"	5.08			62.1	4.861	
313	"	2.25			62.2	2.744	
325	"	16.06			56.0	8.261	
326	"	13.40			55.6	7.448	
327	"	9.58			55.5	6.147	
328	"	6.19			55.5	4.814	
329	"	3.50			55.6	3.475	
407	"	16.78			46.0	8.265	
408	"	13.44			43.2	7.239	
409	"	9.28			41.1	5.864	Temp. Air, 76°. Temp. for Experiments 407 to 412 read in tank.
410	"	5.65			41.3	4.420	
411	"	2.69			42.0	2.898	
412	"	16.96			41.0	8.238	
544	"	16.96			36.0	8.098	
545	"	13.53			36.0	7.160	
546	"	10.26			35.6	6.109	
547	"	6.49			36.0	4.708	
548	"	3.18			36.9	3.128	
549	"	1.12			37.6	1.718	
550	*B-C*	19.36			35.5	8.738	

TABLE No. 4.

Brass Pipe *II*.

No. of Exp't.	Section.	Loss of head, in water. Feet per 100.	Section.	Loss of head, in water. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
1				4.155	36.0°	4.591	
2				2.724	37.4	3.636	Length of section in Experiments 1 to 3 was 57.496 ft. For Experiments 4 to 34, and 714 to 717 length was 57.518 ft.
3				1.342	36.0	2.412	
4				4.746	37.0	4.966	
5				3.637	36.0	4.290	
6				4.440	42.9	4.854	
7				3.963	41.0	4.550	All heads for Pipe *II* were read on water gauges.
8				2.818	41.5	3.737	
9				1.423	41.9	2.533	
10				0.437	42.0	1.281	
11				4.377	49.5	4.838	
12				3.737	49.4	4.473	
13				2.605	49.6	3.651	
14				1.545	49.6	2.713	
15				0.376	50.4	1.202	
16				4.281	55.2	4.889	
17				3.565	55.5	4.413	
18				2.662	55.5	3.734	
19				0.952	55.5	2.076	
20				0.285	....	1.095	
21				4.292	56.1	4.902	
22				2.711	58.5	3.774	
23				1.770	56.0	2.954	
24				0.861	56.0	1.959	
25				3.451	70	4.434	
26				5.341	69.8	5.701	
27				2.811	69.8	3.946	
28				1.604	69.8	2.886	
29				0.892	69.8	2.063	
30				0.562	70.2	1.590	
31				0.410	70	1.323	
32				0.278	69.8	1.043	
33				0.148	69.8	0.735	
34				0.095	70	0.548	
714				5.989	42.4	5.766	
715				1.742	39.0	2.830	
716				0.812	38.5	1.825	
717				2.895	37.0	3.746	

Brass Pipe V.

48	*B–D*	4.179	*D–E*	4.146	70.8°	3.067	† Heads read on mercury gauges.
49	"	3.721	"	3.699	70.1	2.887	
50	"	2.713	"	2.707	70.1	2.415	
51	"	2.275	"	2.288	70	2.179	
52	"	1.896	"	1.885	70	1.959	
53	"	1.187	"	1.119	70	1.488	
54	"	0.527	"	0.546	70	0.942	
55	"	0.185	"	0.182	70	0.517	
209			*B–E*	0.312	71.6	0.751	
210			"	0.260	71.6	0.672	
211			"	0.123	71.6	0.447	
212			"	0.085	71.6	0.359	
263†	*B–D*	25.90	*D–E*	25.22	70.8	8.609	
264†	"	17.94	"	17.80	70.5	7.099	
265†	"	13.56	"	13.44	70.6	6.089	
266†	"	9.28	"	9.14	70.6	4.804	Temp., Air 71°.
299†	"	25.86	"	25.68	61.4	8.535	
300†	"	18.26	"	18.20	61.6	7.044	
301†	"	11.08	"	11.01	61.6	5.285	
302†	"	3.90	"	3.81	61.6	2.896	
347	*D–E*	18.67			54.5	7.030	
348	"	13.72			54.5	5.926	
349	"	8.88			54.5	4.624	
350	"	4.01			54.5	2.927	
351	"	24.67			55.0	8.208	
725	*C–D*	19.87			41	7.054	
726	"	11.56			42.1	5.133	
727	"	28.49			37.2	8.503	
728	"	21.36			36.6	7.200	
729	*D–E*	20.17			40	7.016	
730	"	12.73			39	5.395	
731	"	5.49			39.1	3.845	
732	"	27.33			35.8	8.225	

TABLE No. 4—(*Continued*).

Brass Pipe *IV*.

No. of Exp't.	Section.	Loss of head, in water. Feet per 100.	Section.	Loss of head, in water. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
40			*B–D*	5.61	69.0°	4.097	† Heads were measured in mercury.
42	*B–C*	4.06	*C–D*	4.06	69.1	3.384	
43	"	2.88	"	2.88	69.0	2.794	
44	"	2.03	"	2.04	69.0	2.279	
45	"	1.39	"	1.40	69.0	1.813	
46	"	0.52	"	0.53	69.0	1.019	
47	"	0.17	"	0.19	69.1	0.549	
205			*B–D*	0.145	72.2	0.506	
206			"	0.109	72.1	0.429	
207			"	0.255	72.0	0.695	
208			"	0.371	71.7	0.867	
259†	*B–C*	15.08	*C–D*	14.92	70.1	7.365(?)	Evidently a mistake of 5 seconds in time. V=7.244 therefore used.
260†	"	10.91	"	10.77	73.2	5.975	
261†	"	8.12	"	7.93	72.8	5.052	
262†	"	10.96	"	10.82	71.0	5.994	
303†	"	15.41	"	15.54	62.0	7.135	
304†	"	11.11	"	11.34	62.3	5.959	
305†	"	7.73	"	7.92	62.2	4.839	
306†	"	4.63	"	4.73	62.1	3.687	
307†	"	1.89	"	1.93	62.1	2.154	
303	"	15.43			62.0	7.135	
304	"	11.19			62.2	5.959	
305	"	7.85			62.2	4.839	
306	"	4.67			62.1	3.687	
307	"	1.89			62.1	2.154	
342	"	11.44			54.9	5.946	
343	"	8.30			54.7	4.960	
344	"	5.45			54.6	3.890	
345	"	2.39			54.5	2.427	
346	"	14.39			54.7	6.771	
718	"	12.11			46.5	5.977	
719	"	8.00			43.2	4.698	
720	"	2.82			43.0	2.584	
721	"	14.58			37.2	6.516	
722	"	9.97			37.0	5.969	
723	"	4.99			38.0	3.543	
724	"	2.12			38.5	2.167	

Brass Pipe *VII.*

50	*B–C*	31.09	…………	…………	70.1°	6.762	† Heads read in mercury.
51	"	26.04	…………	…………	70	6.101	
52	"	21.61	…………	…………	70	5.486	
53	"	12.61	…………	…………	70	4.028	
54	"	6.067	…………	…………	70	2.687	
55	"	2.140	…………	…………	70	1.447	
56	"	0.652	…………	…………	70.7	0.728	
195†	*A–C*	77.88	*C–D*	78.10	69.3	11.372	
196†	"	60.95	"	61.24	69.8	9.889	
197†	"	46.97	"	47.11	69.7	8.560	
198†	"	33.18	"	33.05	70.9	7.001	
199	*A–D*	0.440	…………	…………	71.3	0.648	
200	"	0.187	…………	…………	71.3	0.471	
201	"	0.067	…………	…………	71.8	0.218	
380†	*A–C*	78.29	*C–D*	77.04	72.0	11.375	After Experiment 201 Pipe *VII* was taken out and was allowed to remain empty. When set up again, the circulation through the piezometers was poor. Upon investigation, iron rust was found in the slits. These were easily cleaned.
381†	"	79.35	"	78.45	47.5	10.940	
382†	"	67.97	"	67.41	48.0	10.056	
383†	"	52.77	"	52.37	56.1	8.836	
384†	"	41.24	"	40.77	54.6	7.635	
385†	"	31.52	"	30.95	53.2	6.525	
386†	"	21.16	"	21.13	52.5	5.208	
387†	"	10.70	"	10.77	53.0	3.521	
388	"	0.342	"	0.348	85.8	0.538	
389	"	0.334	"	0.331	84.0	0.877	Temp., Air 76° in 383 to 387.
390	"	1.524	"	1.521	81.0	1.230	
391	"	1.203	"	1.206	81.0	1.075	
392	"	2.059	"	2.052	81.0	1.609	
393	"	3.316	"	3.282	77.0	1.881	
469†	"	79.38	"	78.10	40.8	10.686	Air, 71.6°.
470†	"	53.83	"	52.48	47.5	8.708	
471†	"	42.38	"	41.57	46.1	7.542	
472†	"	32.77	"	32.37	45.4	6.512	
473†	"	20.37	"	20.17	46.0	4.949	
474†	"	10.43	"	10.36	46.6	3.361	Air, 64°.
475†	"	81.76	"	80.35	38.2	10.745	
476†	"	67.69	"	66.31	37.8	9.711	
477†	"	49.12	"	48.45	37.5	8.098	
478†	"	35.33	"	34.89	37.3	6.680	

TABLE No. 4—(*Continued*).

BRASS PIPE *VI*.

No. of Exp't.	Section.	Loss of head, in water. Feet per 100.	Section.	Loss of head, in water. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
41	*C–D*	40.15	.....	.....	69.0°	9.316	† Heads read in mercury.
42	"	28.93	.....	.....	69.1	7.712	
43	"	20.47	.....	.....	69.0	6.368	
44	"	14.88	.....	.....	69.0	5.194	
45	"	9.84	.....	.....	69.0	4.183	
46	"	3.66	.....	.....	69.0	2.322	
47	"	1.28	.....	.....	69.1	1.252	
180†	*A–D*	56.22	*D–E*	58.18	69.3	11.477	11.146
181†	"	43.48	"	40.86	69.3	9.933	9.617
182†	"	30.93	"	29.23	70.3	8.212 For *D–E*	7.975 Velocities in *A–B*.
183†	"	21.42	"	20.40	70.3	6.668	6.476
184†	*B–C*	10.54	"	9.94	70.6	4.445	4.317
185	"	59.97	.....	.....	69.3	11.477	
186	"	46.28	.....	.....	69.3	9.933	
187	"	32.84	.....	.....	70.3	8.212	
188	"	22.72	.....	.....	70.3	6.668	After Experiment 193, Pipe *VI* was taken down and remained empty for a time. Upon setting again, the circulation through the piezometers was poor. Iron rust was found in the slits. These were easily cleaned.
189	"	11.12	.....	.....	70.6	4.445	
190	*C–E*	1.56	.....	.....	70.9	1.501	
191	"	1.01	.....	.....	70.9	1.172	
192	"	0.722	.....	.....	71.1	0.962	
193	"	0.433	.....	.....	70.0	0.716	
399	*A–B*	30.11	.....	.....	51.5	7.705	
400	"	24.18	.....	.....	48.0	6.755	
401	"	16.71	.....	.....	47.0	5.470	
402	"	8.90	.....	.....	46.4	3.803	
403	"	1.58	.....	.....	46.6	1.404	
404	"	4.43	.....	.....	47.0	2.448	Air, 74°.
405	"	29.98	.....	.....	44.0	7.590	
406	"	13.19	.....	.....	44.0	4.720	
551†	*C–E*	58.40	.....	.....	36.3	11.055	
552†	"	45.73	.....	.....	36.2	9.683	
553†	"	34.72	.....	.....	37	8.223	
554†	"	24.99	.....	.....	37	6.841	
555†	"	11.54	.....	.....	37.6	4.352	
709†	*C–E*	33.60	.....	.....	79	9.382	
710†	"	39.72	.....	.....	53	9.114	
711†	"	56.74	.....	.....	48.7	11.125	
712†	"	58.90	.....	.....	38	11.181	
713†	"	27.25	.....	.....	45.1	7.270	

BRASS PIPE IX.

64	A-B	73.30	...	...	69.1°	7.668 (?)	
65	"	59.15	...	...	69.5	6.777	
66	"	39.29	...	...	69.6	5.871	
67	"	27.24	...	...	69.9	4.856	
68	"	15.06	...	...	70.1	3.119	
69	"	6.88	...	...	70.5	1.928	
70	"	73.05	...	...	71.0	7.681	
176†	"	172.6	B-C	172.2	67.5	12.23	
177†	"	117.5	"	117.7	67.5	9.884	
178†	"	68.85	"	68.29	69.0	7.286	
179†	"	40.76	"	41.04	69.3	5.384	
275†	"	173.1	"	173.7	66.1	12.31	
276†	"	115.6	"	115.8	65.0	9.758	
277†	"	79.04	"	78.86	65.0	7.855	
278†	"	47.00	"	47.00	65.0	5.830	
283	"	22.24	...	...	66.1	3.882	
284	"	14.08	...	...	67.0	2.908	
285	"	7.375	...	...	67.0	2.011	
286	"	4.89	B-C	4.86	68.0	1.587	
287	"	3.57	"	3.53	68.2	1.348	
288	"	1.71*	"	1.59*	68.4	1.061	
289	"	0.95	"	0.96	68.6	0.849	
290	"	0.58	"	0.60	68.8	0.541	
291	"	0.31	"	0.33	69.0	0.291	
292	"	0.12	"	0.13	69.0	0.111	
338†	"	169.9	"	170.7	55.0	11.91	Air, 67°.
339†	"	130.4	"	131.3	55.5	10.27	
340†	"	78.4	"	79.1	56.0	7.685	
341†	"	54.9	"	55.2	56.3	6.261	
510†	"	118.8	"	120.3	42.8	9.450	
511†	"	75.1	"	76.1	42.1	7.229	
512†	"	41.8	"	42.2	45.0	5.201	
513†	"	177.7	"	180.3	46.5	12.08	
514†	"	168.6	"	171.7	37 7	11.415	
515†	"	137.0	"	138.1	37.6	10.101	
516†	"	110.8	"	112.0	37.3	8.951	
517†	"	86.2	"	87.2	37.5	7.751	
518†	"	55.6	"	56.0	37.8	6.015	Air, 68.5°.
519†	"	27.8	"	27.5	37.9	4.001	

† Heads read in mercury.
* Columns vibrating badly.

In Experiment 64 there was evidently a mistake of 5 lbs. in the weight. This was checked by Experiment 70. Velocity should be 7.652.

TABLE No. 4—(*Continued*).

BRASS PIPE *VIII.*

No. of Exp't.	Section.	Loss of head, in water. Feet per 100.	Section.	Loss of head, in water. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
57	*C-D*	49.55			69.4°	7.448 For *C-D*.	† Heads read in mercury.
58	"	40.30			69.4	6.622	* Columns vibrating badly.
59	"	32.64	*A-B*	33.49	69.4	5.833	5.895
60	"	20.59	"	21.25	69.4	4.501	4.549
61	"	11.96*	"	12.81*	69.4	3.300	3.335 Velocities for *A-B*.
62	"	4.40	"	4.54	60.4	1.850	1.870
63	"	1.38	"	1.50	69.4	0.947	0.957
172	*B-C*	48.96			67.5	6.941	
173	"	29.05			67.5	5.584	
174	"	17.63			69.0	4.117	
175	"	10.51			69.8	3.018	
168†	*A-B*	45.23	*B-D*	44.05	67.5	7.015 For *C-D*.	
169†	"	30.81	"	30.09	67.5	5.644	Velocities for *B-D* same as for *B-C*. Experiments 172 to 175.
170†	"	17.58	"	17.49	69.0	4.161	
171†	"	10.82	"	10.58	69.3	3.016	
279†	*C-D*	44.86			66.1	6.956	
280†	"	29.91			65.0	5.513	
281†	"	20.85			65.0	4.439	
282†	"	12.43			65.0	3.288	
379†	"	44.2			53.0	6.691	
394	"	30.66			51.5	5.389	
395	"	22.78			52.2	4.558	
396	"	15.07			52.3	3.584	Air, 67°.
397	"	6.18			53.3	2.150	
398	"	6.55			54.6	2.216	
556†	*A-B*	183.1			71	14.97	
557†	"	194.9			37	14.545	
558†	"	160.7			36.7	13.08	
559†	"	134.3			36	11.77	
560†	"	108.4			36	10.15	
561†	"	81.3			36.1	8.791	Air, 66°.
562†	"	58.6			36.1	7.370	
563†	"	38.5			36.3	5.770	
564†	"	28.4			36.5	4.832	
565†	"	134.6			39.2	11.87	
566†	"	114.6			48.8	10.99	
567†	"	80.8			48.4	9.063	
568†	"	54.0			49.0	7.252	
569†	"	26.5			49.2	4.824	Air, 66°.

BRASS PIPE *XI.*

80	*A-B*	48.99	....	....	69.0°	4.567	†Heads read in mercury.
81	"	29.37	....	....	69.0	3.626	
82	"	18.91	....	....	69.0	2.818	
83	"	11.55	....	....	69.0	2.127	
84	"	4.19	....	....	69.0	1.375	
133†	"	69.44	*B-C*	70.76	67.8	5.958	
134†	"	56.29	"	57.52	67.8	5.271	
135†	"	46.15	"	46.99	67.6	4.704	
136†	"	37.35	"	38.30	69.0	4.182	
137†	"	25.98	"	26.72	69.7	3.409	
138†	"	15.05	"	15.66	70.0	2.517	
139†	"	8.70	"	9.08	70.0	1.882	
372†	"	185.1	"	187.9	69.0	8.741	In 372 and 373 the discharge valve remained in the same position. They show the temperature effect on the discharge very clearly.
373†	"	185.3	"	188.2	56.5	8.497	
374†	"	206.4	"	210.8	57.5	10.872	
375†	"	173.9	"	177.7	58.0	9.854	
376†	"	103.3	"	105.3	55.8	7.261	
377†	"	66.8	"	68.1	55.8	5.651	
378†	"	32.1	"	32.9	56.3	3.726	
479†	"	198.3	"	201.4	37.9	10.077	Pipe *XIII* removed, 372 to 492.
480†	"	158.7	"	161.4	37.8	8.918	Air, 67°.
481†	"	124.2	"	126.2	37.0	7.685	
482†	"	92.3	"	93.9	37.0	6.513	
483†	"	57.9	"	58.8	37.1	4.975	
484†	"	19.1	"	19.4	37.4	2.714	Air, 68°.
485†	"	197.4	"	201.2	47.6	10.386	
486†	"	130.1	"	132.8	49.1	8.238	
487†	"	198.5	"	201.9	39.1	10.170	Air, 69°.
488†	"	198.4	"	201.8	41.1	10.206	
489†	"	199.0	"	202.6	43.9	10.266	
490†	"	283.5	....	....	48.5	12.751	Section *B-C* removed.
491†	"	286.5	....	....	39.9	12.534	
492†	"	233.1	....	....	43.0	11.848	

TABLE No. 4—(*Continued*).

Brass Pipe *X*.

No. of Exp't.	Section.	Loss of head, in water. Feet per 100.	Section.	Loss of head, in water. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
71	*A-B*	48.38			70.3°	5.311	† Head read in mercury.
72	"	33.20			70.6	4.278	
73	"	21.19			70.7	3.301	
74	"	9.28			71.0	2.056	
75	"	2.59			71.0	1.107	
147†	"	76.72	*B-C*	76.77	68.3	6.914	
148†	"	59.75	"	59.78	68.0	5.972	
149†	"	40.00	"	40.16	68.0	4.772	
150†	"	29.57	"	29.75	68.0	3.895	
151†	"	17.06	"	16.55	68.1	2.939	
152†	"	11.17	"	11.54	68.3	2.333	
153†	"	3.93	"	3.95	68.7	1.335	
354†	"	51.05	"	51.09	68.1	5.483	
355†	"	50.99	"	50.95	56.6	5.340	
356†	"	78.43	"	78.81	54.0	6.796	
357†	"	40.44	"	40.56	56.2	4.681	
358†	"	15.93	"	16.00	55.2	2.749	
529†	"	181.9	"	181.4	64.8	11.321	
530†	"	148.2	"	147.8	55.2	9.828	
531†	"	114.6	"	114.3	51.0	8.411	
532†	"	180.0	"	178.7	74.1	11.387	
533†	"	139.1	"	137.8	73.4	9.818	
534†	"	173.9	"	173.9	42.5	10.462	
535†	"	145.0	"	145.2	42.0	9.385	
536†	"	110.2	"	110.6	44.0	8.057	
537†	"	74.6	"	75.0	45.2	6.450	
538†	"	171.7	"	171.3	38.0	10.276	
539†	"	127.6	"	127.8	37.1	8.636	
540†	"	92.6	"	93.0	37.2	7.182	
541†	"	56.4	"	56.5	37.2	5.838	
542†	"	32.8	"	33.7	37.1	3.970	
543†	"	149.4	"	149.0	36.7	9.445	

BRASS PIPE XIII.

85.	A B	49.61	....	....	69.6°	4.115	† Heads read in mercury.
86.	"	33.48	....	....	69.6	3.294	* Columns vibrating badly; vibrations greater in 293 than in 294; critical-velocity region.
87.	"	17.21	....	....	69.6	2.250	
88.	"	5.60	....	....	69.6	1.882	
140†	"	217.4	B-C	218.1	67.8	9.635	
141†	"	176.6	"	177.2	67.8	8.581	
142†	"	144.3	"	144.8	68.6	7.615	
143†	"	117.5	"	117.5	69.0	6.658	
144†	"	82.0	"	82.4	69.7	5.426	
145†	"	48.3	"	48.6	70.0	4.007	
146†	"	27.9	"	28.0	70.0	2.917	
293.	"	7.11*	"	7.99*	60.6	1.765	
294.	"	5.99*	"	6.56*	61.0	1.215	
295.	"	4.47	"	4.47	61.5	1.270	
296.	"	3.18	"	3.15	62.0	0.898	
297.	"	1.85	"	1.87	62.1	0.540	
298.	"	0.91	"	0.84	62.4	0.267	
319†	"	220.3	"	220.8	65.2	9.578	
320†	"	148.2	"	144.1	65.2	7.507	
321†	"	76.6	"	77.3	65.2	5.231	
330†	"	187.6	"	188.4	56.5	7.229	
331†	"	83.8	"	84.5	56.5	5.418	Air, 70°.
332†	"	192.5	"	193.5	56.5	8.775	
493†	"	406.7	....	....	63.2	13.651	
494†	"	300.3	....	....	60.8	11.43	
495†	"	408.3	....	....	46.2	13.20	Air, 67°. Removed *XI*, except entry length and piezometer *A*. End length of *XI*, with reducer, screwed into *A*. *XIII* *B-C* removed.
496†	"	358.7	....	....	48.6	12.22	
497†	"	282.4	....	....	47.4	10.71	
498†	"	213.2	....	....	46.8	9.097	
499†	"	209.2	....	....	38.2	8 777	
500†	"	302.5	....	....	36.3	10.780	
501†	"	402.5	....	....	37.4	12.78	
502†	"	252.9	B-C	253.6	50.0	10.07	*B-C* put on.
503†	"	199.7	"	201.2	50.0	8.836	
504†	"	124.3	"	125.1	47.0	6.664	
505†	"	81.7	"	82.0	46.0	5.227	
506†	"	26.4	"	27.2	39.0	2.744	
507†	"	64.0	"	63.9	38.8	4.448	Air, 65°.
508†	"	112.7	"	114.0	38.5	6.182	
509†	"	155.9	"	158.4	38.9	7.468	

TABLE No. 4—(*Continued*).

Brass Pipe *XII*.

No. of Exp't.	Section.	Loss of head, in water. Feet per 100.	Section.	Loss of head, in water. Feet per 100.		Temp. Fahr.	Velocity, in feet per second.				Remarks.
76	*A-B*	55.18				72.0°	4.940				† Heads read in mercury.
77	"	39.17				72.3	4.002				
78	"	21.32				72.4	2.865				
79	"	9.53				72.5	1.809				
154†	"	205.9	*B-D*	187.3	For *C-D*	68.3	10.477	For *A-B*	10.165	For *B-D*	
155†	"	160.4	"	146.3		68.0	9.050		8.780		
156†	"	107.7	"	98.04		68.0	7.232		7.016		
157†	"	80.08	"	73.15		68.0	5.903		5.727		
158†	"	46.63	"	42.56		68.1	4.454		4.321		
159†	"	31.16	"	28.41		68.3	3.536		3.430		
160†	"	11.74	"	10.47		68.7	2.023		1.963		
161			*B-C*	185.6		68.3	10.165				Experiments 161 to 167 were simultaneous with 154 to 160. The heads were read on a water gauge. The heads given for *B-D* (154 to 160) are really for *C-D*, the *B-C* heads (161 to 167) having been subtracted.
162			"	144.8		68.0	8.780				
163			"	97.4		68.0	7.016				
164			"	73.32		68.0	5.727				
165			"	43.27		68.1	4.321				
166			"	28.15		68.3	3.430				
167			"	10.52		68.7	1.963				
267†	*A-B*	135.4	*C-D*	124.2		68.8	8.270	*A-B*	8.024	*C-D*	
268†	"	73.22	"	67.4		69.2	5.817		5.644		
269†	"	133.0	"	122.2		65.0	8.137	*A-B*	7.895	*C-D*	
270†	"	104.4	"	95.94		65.0	7.088		6.877		
271†	"	64.85	"	59.34		65.0	5.362		5.208		
272†	"	48.35	"	44.59		65.0	4.556		4.422		
273†	"	28.92	"	26.61		65.0	3.390		3.290		
274†	"	207.2	"	190.2		65.3	10.510		10.197		
352†			"	125.2		68.1			8.061	*C-D*	
353†			"	125.0		56.6			7.850		Air, 68°.
359†			"	192.6		54.0			10.004		
360†			"	156.7		55.1			8.910		
361†			"	82.8		55.0			6.172		Air, 67°.
362†			"	34.6		56.0			3.738		
520†	*A-B*	202.7	"	186.1		45.4	9.907	*A-B*	9.612	*C-D*	
521†	"	145.8	"	133.4		45.4	8.170		7.927		
522†	"	81.2	"	74.2		45.7	5.843		5.669		
523†	"	268.7				54.9	12.425				*B-D* removed.
524†	"	249.5				58.0	11.375				Air, 71.5°.
525†	"	235.1				39.0	10.609				
526†	"	238.1				39.4	11.910				
527†	"	243.5				43.0	10.950				
528†	"	290.0				45.6	12.175				

Brass Pipe XV.

94.	A-B	44.58	....	....	70.6°	2.892	†Heads read in mercury.
95.	"	33.83	....	....	70.6	2.596	
96.	"	19.26	....	....	70.6	2.362	
97.	"	8.623	....	....	70.0	1.248	
98.	"	2.001	....	....	70.0	0.300	
117†	"	180.2	B-C	194.2	69.5	6.761	
118†	"	155.4	"	167.6	70.0	5.946	
119†	"	129.6	"	139.5	70.0	5.384	
120†	"	99.9	"	107.6	70.2	4.630	
121†	"	67.84	"	72.47	70.4	3.730	
122†	"	18.60	"	20.72	70.9	1.953	
123†	"	275.8	"	299.3	70.6	8.304	
124†	"	218.4	"	235.6	71.0	7.249	
222†	"	510.5	....	....	74.8	11.868	*B-C* removed.
223†	"	411.4	....	....	75.5	10.519	
224†	"	319.1	....	....	76.0	9.102	
225†	"	207.7	....	....	75.7	7.109	
226†	"	114.2	....	....	75.1	5.075	
227†	"	45.32	....	....	73.9	3.009	
228†	"	29.05	....	....	73.1	2.394	
229†	"	18.16	....	....	73.0	1.952	
230†	"	9.33	....	....	73.1	1.362	
237†	"	278.4	B-C	303.3	72.9	8.398	
238†	"	179.2	"	194.5	70.9	6.537	
239†	"	122.7	"	133.7	73.6	5.277	
240†	"	273.4	"	298.4	70.7	8.217	Pipes Nos. 2 and 3 interchanged, placing Section *B-C* up stream.
241†	"	238.5	"	255.4	70.8	7.575	
242†	"	151.4	"	164.6	71.0	5.902	
253†	"	281.9	"	294.1	70.2	8.489	Pipes cleaned. *A-B* up stream.
254†	"	227.5	"	228.0	70.3	7.500	
255†	"	145.4	"	146.2	70.4	5.852	
256†	"	52.55	"	52.66	70.7	3.276	
257†	"	32.58	"	33.84	71.7	2.537	
258†	"	11.41	"	11.53	72.9	1.767	
368†	"	174.4	"	175.2	58.7	6.257	
369†	"	242.0	"	243.0	55.0	7.578	
370†	"	292.2	"	293.4	55.4	8.460	
371†	"	102.2	"	102.6	56.0	4.682	
413†	"	270.1	"	271.0	46.0	7.800	
414†	"	176.2	"	177.1	47.5	6.145	
415†	"	175.7	"	176.8	47.0	6.188	Air, 68°.
416†	"	109.8	"	110.4	49.6	4.781	
417†	"	52.3	"	53.0	45.7	3.183	Air, 69.5°.

TABLE No. 4—(*Continued*).

BRASS PIPE *XIV*.

No. of Exp't.	Section.	Loss of head, in water. Feet per 100.	Section.	Loss of head, in water. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
246†	*A-B*	304.0	*B-C*	308.8	70.2°	9.957	NOTE: Experiments 89 to 93, 125 to 132, 231 to 236, were rejected. The results on the two sections were not consistent, and when the pipe was taken down the ends were found to be jammed. (This pipe is very thin.) The jammed ends were cut off, and the pipes were refaced and rethreaded. Subsequent examinations showed no trouble.
247†	"	236.3	"	240.6	70.3	8.618	
248†	"	154.1	"	157.1	70.4	6.685	
249†	"	97.16	"	96.73	70.7	5.179	
250†	"	54.49	"	55.05	71.7	3.722	
251†	"	28.92	"	29.28	72.9	2.608	
252†	"	12.49	"	13.80	73.5	1.743	
363†	"	203.0	"	206 4	54.8	7.661	
364†	"	151.7	"	154.5	56.0	6.483	
365†	"	89.6	"	91.5	56.4	4.813	
366†	"	39.0	"	39.8	56.8	2.943	Air, 67.5°.
367†	"	310.5	"	317.1	54.1	9.760	
447†	"	202.0	"	204.7	47.2	7.427	Air, 76°.
448†	"	163.3	"	166.0	44.4	6.548	
449†	"	134.4	"	136.4	45.8	5.870	Air, 68.5°.
450†	"	96.4	"	97.9	42.4	4.859	
451†	"	61.5	"	62.2	42.8	3.780	
452†	"	35.7	"	36.6	42.2	2.825	Air, 66.5°.
453†	"	302.3	"	306.8	42.3	9.314	
454†	"	256.4	"	260.2	49.4	8.584	
455†	"	571.3	....	....	61.4	14.011	
456†	"	479.7	....	....	59.8	12.659	Air, 72°.
457†	"	373.1	....	....	59.8	10.936	
458†	"	266.8	....	....	60.8	9.047	
459†	"	265.8	....	....	42.5	8.625	Air, 71°.
460†	"	359.0	....	....	45.0	10.333	
461†	"	442.6	....	....	47.9	11.772	
462†	"	565.7	....	....	48.8	13.566	Air, 74°.
463†	"	555.7	....	....	37.8	13.036	Air, 68°.
464†	"	517.3	....	....	38.8	12.567	
465†	"	429.5	....	....	38.0	11.370	
466‡	"	324.4	....	....	37.5	9.569	Air, 65.8°.
467†	"	216.5	....	....	37.6	7.558	
468†	"	93.3	....	....	37.6	4.792	Air, 65°.

† Heads read in mercury.

Brass Pipe *XVI.*

99	*A-B*	44.46	...	...	67.7*	2.676	† Heads read in mercury. * Sudden change in gauge columns, probably due to the settling of the valve.
100	"	23.59	...	...	68.0	2.074	
101	"	18.29	...	...	69.0	1.378	
102	"	7.804	...	...	69.5	0.602	
103†	"	178.6	*B-C*	178.4	70	5.135	
104†	"	186.7	"	186.6	70.2	4.424	
105†	"	105.4	"	105.2	70.9	3.840	
106†	"	76.4	"	76.6	71.0	3.280	
107†	"	48.29	"	48.6	71.2	2.721	
108†	"	24.15	"	23.0	71.9	1.790	
109†	"	60.61	"	62.36	69.5	2.917	
110†	"	56.53	"	58.49	70.0	2.866	
111†	"	37.36	"	38.42	70.0	2.559	
112†	"	31.94	"	31.98	70.2	2.309	
113†	"	11.72	"	11.71	70.4	0.911	
114†	"	5.86	"	5.97	70.9	0.451	
115†	"	271.4	"	276.6	70.6	6.542	
116†	"	229.9	"	234.7	71.0	5.993	
213†	"	512.8	...	...	74.5	9.448	*B-C* removed.
214†	"	423.0	...	...	75.0	8.467	
215†	"	323.9	...	...	75.1	7.277	
216†	"	231.1	...	...	75.2	6.001	
217†	"	124.6	...	...	75.3	4.255	
218†	"	47.25	...	...	75.1	2.620	
219†	"	32.24	...	...	75.1	2·282	
220†	"	19.89	...	...	75.1	1.614	
221†	"	8.97	...	...	75.2	0.730	
243†	"	276.6	*B-C*	280.5	70.7	6.606	Pipes Nos. 2 and 3 interchanged, placing section *B-C* up stream.
244†	"	227.0	"	230.2	70.8	5.816	
245†	"	136.2	"	187.9	71.0	4.437	
314†	"	178.0	"	180.7	64.3	5.107	Section *A-B* up stream.
315†	"	129.3	"	131.6	64.5	4.298	
316†	"	76.47	"	80.14	64.8	3.248	
317†	"	39.12	"	37.27	65.0	2.523	
318†	"	284.2	"	288.2	65.0	6.645	
322†	"	521.1	"	...	64.0	9.337	*B-C* removed.
323†	"	446.1	...	...	64.0	8.552	
324†	"	324.5	...	...	64.0	7.143	
333†	"	496.8	...	...	55.0	8.940	
334†	"	388.2	...	...	55.8	7.809	

TABLE No. 4—(*Continued*).

BRASS PIPE *XV*—(*Continued*).

No. of Exp't.	Section.	Loss of Head, in water. Feet per 100.	Section.	Loss of Head, in water. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
418†	*A–B*	287.8			44.1	8.168	
419†	"	443.9			43.2	9.991	No. 419 seems erratic. No. 443 taken as a check.
420†	"	364.3*			46.4	9.254	
421†	"	440.7			38.2	10.237	*In No. 420 the head decreased by jumps, probably due to the valve settling slightly.
422†	"	374.3			38.0	9.327	
423†	"	314.1			37.7	8.450	
424†	"	255.7			37.6	7.522	Air, 69°.
425†	"	194.3			37.6	6.444	
426†	"	182.6			37.5	5.194	Air, 66°.
427†	"	71.4			37.6	3.752	
443†	"	440			43.7	10.344	
444†	"	461.4			45.8	10.695	
445†	"	408.7			46.2	9.965	
446†	"	325.9			46.1	8.759	Air, 71°.

TABLE No. 4 —(*Continued*).

BRASS PIPE *XVI*—(*Continued*).

No. of Exp't.	Section.	Loss of Head, in water. Feet per 100.	Section.	Loss of Head, in water. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
335†	*A-B*	267.0*	....	....	56.5	6.327	Air, 62°.
336†	"	250.8	....	....	57.0	6.130	
337†	"	110.1	....	....	57.4	3.870	
428†	"	496.8	....	....	43.5	8.746	
429†	"	409.8	....	....	45.0	7.869	
430†	"	307.8	....	....	47.8	6.754	Air, 78°.
431†	"	307.4	....	....	39.4	6.659	
432†	"	389.9	....	....	38	7.562	
433†	"	436.2	....	....	38.3	8.047	
434†	"	481.0	....	....	38.6	8.516	
435†	"	267.9	*B-C*	271.1	39.0	6.140	Air, 65°.
436†	"	213.5	"	216.6	39.0	5.424	
437†	"	158.7	"	162.6	38.6	4.751	
438†	"	103.2	"	101.3	38.5	4.071	Air, 68°.
439†	"	66.7	"	64.9	38.5	3.142	
440†	"	33.7	"	33.0	38.5	1.635	
441†	"	19.1	"	18.8	38.4	0.958	
442†	"	7.2	"	7.2	38.3	0.387	

TABLE No. 5.—Galvanized Pipe *XVII.*

No. of Exp't.	Loss of head. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
592	70.89	35.5°	10.086	All heads measured in mercury.
593	39.90	35.8	7.493	
594	54.00	44.4	8.762	
595	39.59	42.5	7.452	Air, 64°.
596	25.85	41.2	6.008	
597	13.17	40.9	4.229	
598	5.88	41.2	2.795	
599	62.46	35.5	9.374	
600	55.35	35.6	8.476	
601	28.75	35.6	6.340	
602	16.51	36.4	4.766	
620	44.19	59.5	7.955	
621	26.21	51.2	6.092	
741	44.87	79	8.375	Experimental pipe reversed (Piezometer *B* up stream) for these experiments.
742	43.89	43.6	7.813	
743	43.67	35.6	7.711	
744	74.36	35.4	10.155	
745	73.74	35.2	10.118	
746	55.61	35.5	8.860	
747	26.82	35.2	6.041	
748	13.21	35.4	4.216	
749	7.87	35.6	3.111	

Galvanized Pipe *XVIII.*

No. of Exp't.	Loss of head. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
631	51.61	44.6°	9.469	All heads measured in mercury.
632	41.11	42.9	8.321	
633	30.06	42.4	7.060	
634	20.60	42.0	5.708	
635	10.40	42.5	3.913	
636	4.99	42.8	2.618	
637	75.83	36.0	11.470	
638	64.87	36.0	10.554	
639	50.87	71.5	9.635	
640	32.41	64	7.548	
641	74.37	39.8	11.427	
642	74.89	35.8	11.405	
643	50.10	36.1	9.159	
644	35.74	36.2	7.757	
645	19.99	35.8	5.518	
646	8.47	36.5	3.423	
737	51.74	37	9.271	Experimental pipe reversed (Piezometer *B* up stream) for these experiments.
738	31.00	37.2	7.047	
739	15.52	38.2	4.811	
740	71.22	35.1	10.916	

TABLE No. 5—*Continued.*—GALVANIZED PIPE *XIX.*

No. of Exp't.	Loss of head. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
622	96.62	55.0°	10.223	All heads measured in mercury.
623	61 20	49	7.909	
624	33.62	48	5.747	
625	16.72	48.2	3.894	
626	7.36	49.2	2.460	
627	143.31	77	12.783	
628	144.72	37.5	12.339	
629	80.22	37.5	9.049	
630	37.70	37.7	5.996	
755	98.04	78	9.994*	
756	97.56	50	10.079	
757	97.70	50.7	10.248	Experimental pipe reversed for these experiments.
758	78.17	52.0	9.028	
759	78.18	49.0	9.011	
760	39.71	48.5	6.267	
761	22.81	49.0	4.610	* Error in time? Velocity may be 10.316. See Experiment 768.
762	148.47	48.6	12.560	
763	149.69	37.1	12.578	
768	98.16	77.2	10.298	
769	77.00	80.2	9.196	
770	77.88	45.9	8.931	
771	97.65	45.8	10.062	

GALVANIZED PIPE *XX.*

No. of Exp't.	Loss of head. Feet per 100.	Temp. Fahr.	Velocity, in feet per second.	Remarks.
603	166.6	61.5	10.885	All heads measured in mercury.
604	109.1	58.8	8.725	
605	165.6	37.2	10.653	
606	149.6	36.8	10.145	
607	116.5	35.9	8.877	
608	79.15	35.5	7.240	
609	46.20	35.6	5.499	
610	21.12	35.8	3.634	
611	10.34	39.0	2.487	
612	5.03	40.6	1.669	
613	118.3	42.6	8.781	
614	91.35	49.5	7.877	
615	112.6	47.0	8.775	
616	59.93	46.4	6.308	
617	112.2	77.2	8.896	
618	51.56	78.3	5.965	
619	164.5	79.2	10.884	
764	166.4	48.4	10.744	Experimental pipe reversed for these experiments.
765	108.2	45.2	8.607	
766	57.4	45.2	6.156	
767	25.9	52	4.077	

TABLE No. 5—*Continued.*—GALVANIZED PIPE *XXI.*

No. of Exp't.	Loss of head. Feet per 100.	Temp. Fahr.	Velocity in feet per second.	Remarks.
570	403.5	71.5°	11.411	All heads measured in mercury.
571	205.1	71.5	8.009	
572	341.5	68	10.394	
573	257.2	54	8.956	
574	181.3	52.2	7.489	
575	125.6	59.2	6.219	
576	84.71	57.8	5.085	
577	53.77	57.1	4.039	
578	31.68	59.8	3.067	
579	374.9	38.5	10.763	
580	311.8	38.6	9.830	
581	258.4	37.4	8.938	
582	195.3	37.4	7.739	
583	133.8	37.5	6.394	
584	84.05	38.0	5.025	
585	47.50	38.4	3.756	
586	5.97	42.6	1.305	
587	11.94	44.0	1.856	
588	25.69	47.2	2.744	
589	268.1	46.3	9.112	
590	142.6	47.8	6.621	
591	388.3	49.7	10.992	
750	316.5	45.1	9.795	Experimental pipe reversed (Piezometer *B* up stream) for these experiments.
751	315.4	36.4	9.651	
752	244.5	38.9	8.464	
753	161.7	36.4	6.834	
754	77.7	39.0	4.731	

REDUCTION TO STANDARD TEMPERATURES.

Brass Pipes.—After a few experiments had been made on each pipe, a preliminary logarithmic plotting of the results showed that for each of the fifteen brass pipes the loss of head varied very nearly as the 1.75 power of the velocity. Advantage was taken of this fact to bring the results to chosen standard temperatures. Plates XXXVIII and XXXIX were drawn, using heads in feet per 100 ft. as ordinates and the values of $V^{1.75}$ as abscissas. For any particular pipe on these plates, it will be noticed that there is a gradual increase in the ordinate as the temperature of the water drops, and that points of about the same temperature lie approximately on a straight line. Such lines were drawn for standard temperatures of 70, 55 and 40° Fahr. The difference in ordinates between two lines, divided by the ordinate, gives the ratio or percentage of increase or decrease in the loss of head for a change of temperature of 15 degrees. The percentage is always less for 40° than for 55°, as the ordinate itself is greater. In those cases in which the distances between the lines were different, thus resulting in two different percentages at 55°, the average of these two percentages was taken. The three percentages reduced to percentages per 10°, instead of 15°, were then plotted as ordinates, with temperatures as abscissas, and a smooth curve was drawn through the three points. The percentage correction per 10° for any observed temperature was read from these curves. The diagram used is shown in Fig. 3, in which it will be seen that for all pipes the correction factor is about 4 per cent. Another diagram was therefore constructed, from which the 4% corrections of the different heads for any temperature interval could be read, and the correction desired was then obtained by the slide-rule.

PERCENTAGES PER 10 DEGREES USED IN BRINGING OBSERVED RESULTS TO STANDARD TEMPERATURES 70°, 55° AND 40°.

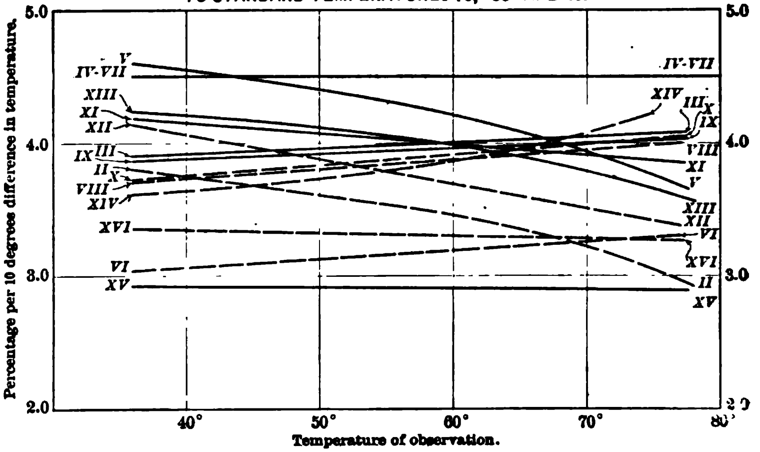

Fig. 3.

In Fig. 3 it will be noticed that for some pipes the percentage curves slope downward for increasing temperatures, and for other pipes there is an opposite tendency. While it is not to be maintained that these corrections are accurate, it is believed that they are correct within several tenths of 1 per cent. If this is true, a profile view of Fig. 3, at 70°, 55° or 40°, made by taking the percentages and plotting them with respect to the pipe diameters, gives indications of a sinuous relation between the temperature effects and the diameters. The evidence, however, is not conclusive enough to justify the statement that this is a fact.

Aside from errors in judgment in drawing the lines on Plates XXXVIII and XXXIX, there is at least one way in which small errors

PLATE XXXVIII.
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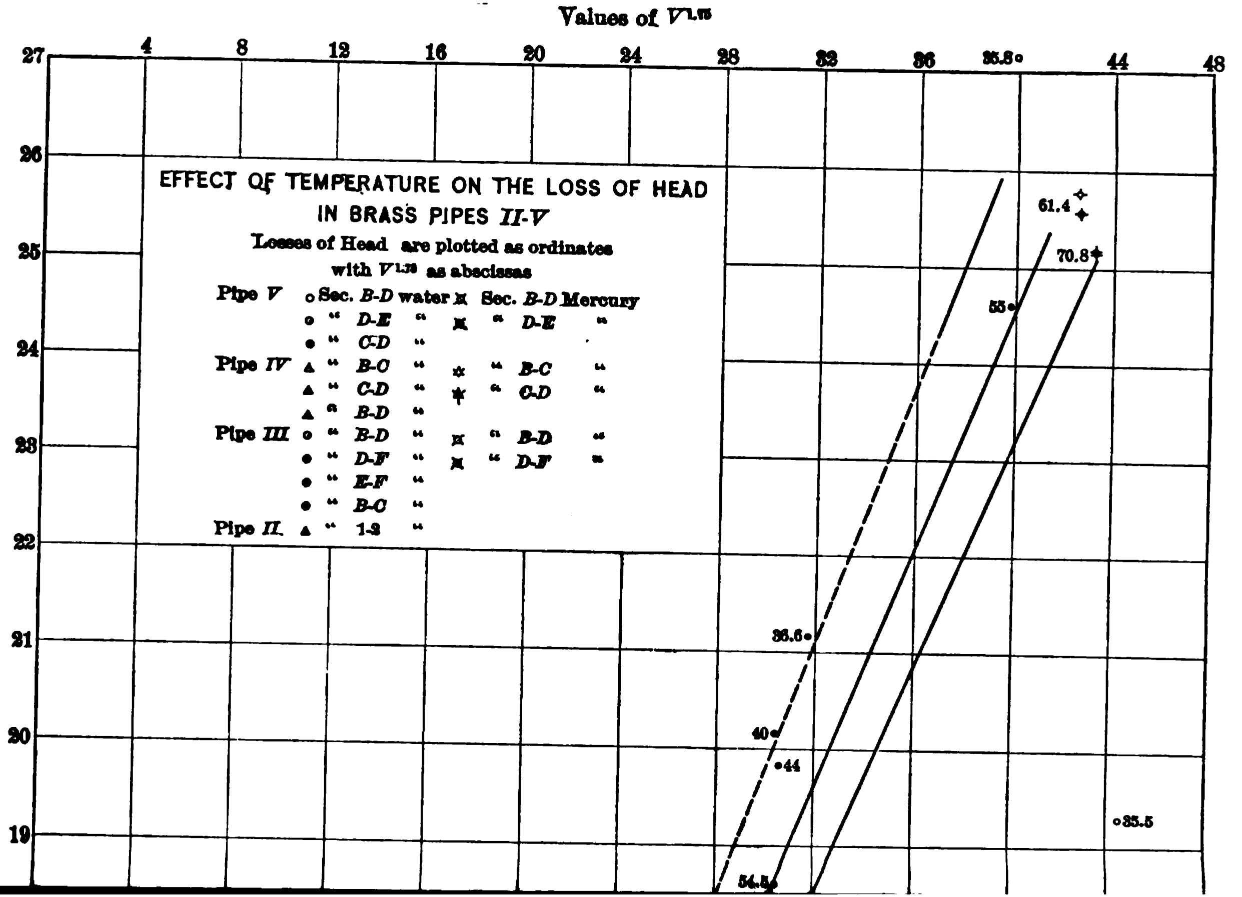

EFFECT OF TEMPERATURE ON THE LOSS OF HEAD IN BRASS PIPES *II-V*

Losses of Head are plotted as ordinates with $V^{1.75}$ as abscissas

might be introduced into the reduction factor. It will be seen later, in the tables for m and n, that for the different standard temperatures there are slight differences in the value of n for a certain pipe, and sometimes quite decided differences between these values of n and the preliminary value, 1.75. The differences in the values of n would result in changing the relative position of the lines, as they are all drawn upon the basis of $n = 1.75$. The fact that n is sometimes different from 1.75 results in giving a slight curvature to the line passing through the points at a certain temperature. As stated, however, the errors are not large, and, taking into consideration the fact that the correction intervals were in almost all cases less than 10°, it is certain that the limits of error mentioned have not been exceeded. In addition, the corrections were usually made from both sides of the standard temperatures, and any appreciable error would be evident at once in the plotting.

Another method for getting the temperature correction consists in plotting the values of $m = \frac{H}{V^{1.75}}$ as ordinates, with the temperatures as abscissas. When this is done, a straight line results in some cases and a curve in others. It usually gives the same results as the method already presented, but, taken altogether, it is not as reliable.

Galvanized Pipes.—For the galvanized pipes, a diagram was made, as for the brass pipes, using for the abscissas those approximate powers of the velocity which a preliminary logarithmic plotting showed for each pipe. These powers or values of n were quite variable, as the following values show.

	n
Pipe *XVII*	1.95
" *XVIII*	1.82
" *XIX*	1.82
" *XX*	1.90
" *XXI*	1.95

The diagram, however, did not give such consistent results as did the diagrams for brass pipes. The experiments were mostly in the neighborhood of 40 degrees. The results were usually somewhat erratic, and in many cases the estimate had to be based on the assumption of a uniform change from 70 to 37 degrees. Upon passing to the final plotting, however, these estimates, which varied from 1 to 2%

for 10° difference in temperature, showed themselves to be in err More consistent reduction factors were obtained by using large-sc logarithmic paper for a preliminary plotting. Upon Pipes *XVII* a *XXI* very little evidence of temperature effect could be found, a the results were not corrected. For Pipe *XIX* 1.5% for 10° w found to apply; and for Pipe *XX* 1.25% was used. For Pipe *XV* the results were changed by 5% in the neighborhood of 40°, but, fr all appearances, this would be too large in the vicinity of 70 degre Pipe *XVIII*, however, seems to be exceptional, in several respects.

Logarithmic Plotting of Results.—After being brought to the stand temperatures the results were plotted on regular, 10-in. base, logari mic, cross-section paper,* plotting losses of head as ordinates a velocities as abscissas. The use of such paper is now so common th no explanation is considered necessary.

This plotting is shown in Plate XL, which contains the results f both brass and galvanized pipes, plotted, however, for differ origins. For the brass pipes, lines are drawn for the three standa temperatures, but for only one experimental section on each pipe, order to avoid confusion.

Close inspection will show that in some instances the points do n lie exactly on the line. In such cases investigation was made to se the reason existed in an error in the temperature reduction factor, b it was found that the differences were due to other causes. So times the results obtained by mercury readings were slightly differ from those taken in water. Altogether, however, the lines fit t points very well. Attention may be called here to the great unifor ity in slope for the brass pipes.

Table No. 6 gives the values of m and n, as determined from t logarithmic plotting. In cases, however, where the points do not exactly on a straight line, or where, as in Pipe *XVI* at 40°, the poi which determine the line are few in number, and for high velociti there is usually a little uncertainty in drawing the line. In this w small variations in m may be brought about, but when it is cons ered that there is a corresponding change in n, it will be seen that two values taken together will represent the conditions quite ac rately.

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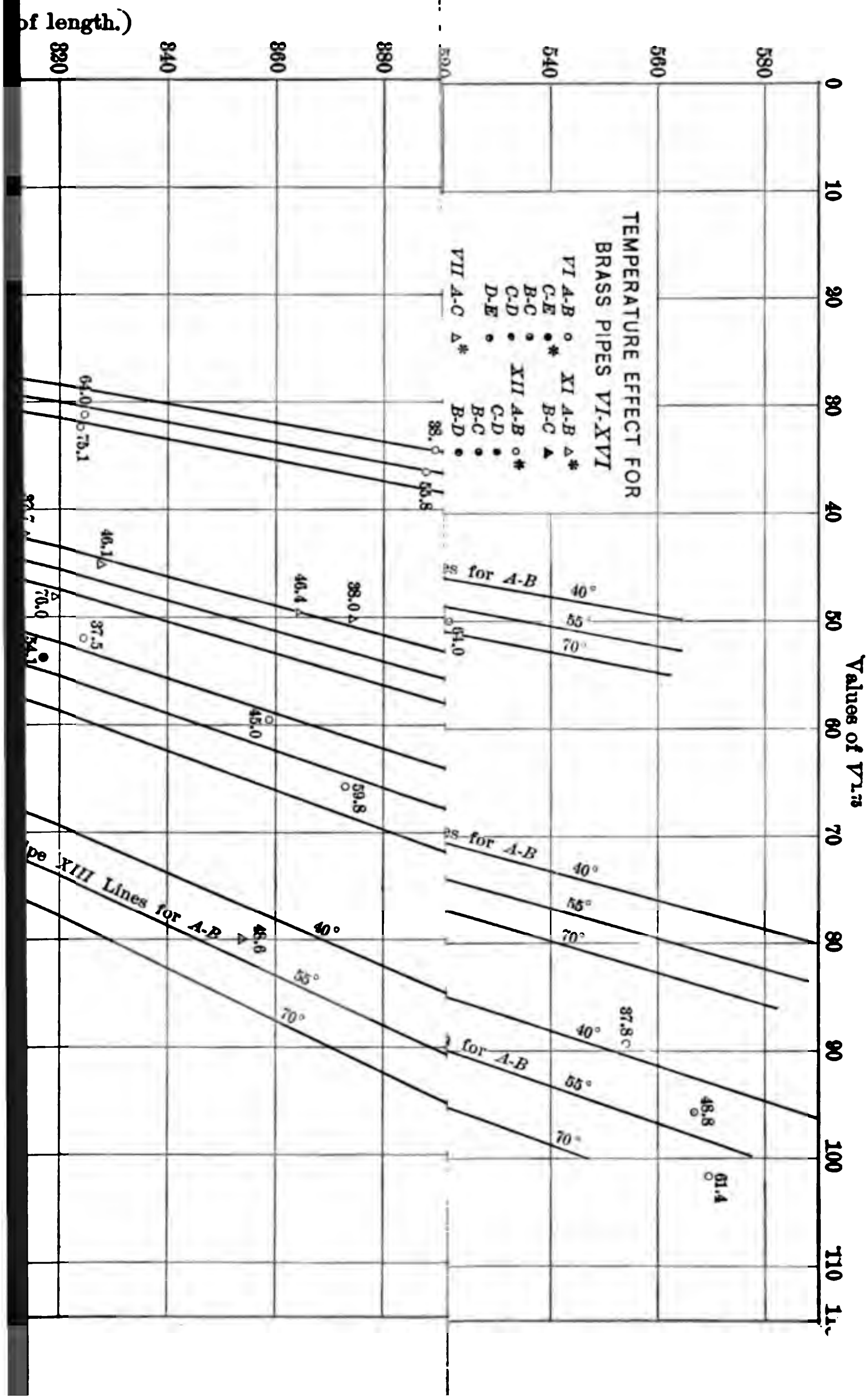
* The writers were supplied with this paper by John R. Freeman, M. Am. Soc. C. whose generosity and kindly interest they desire to acknowledge.

PLATE XXXIX.
PAPERS, AM. SOC. C. E.
MAY, 1908.
SAPH AND SCHODER ON
FLOW OF WATER IN PIPES.



In Table No. 6 there will also be found the values of *m*, as taken from Plates XXXVIII and XXXIX on which the points were plotted with heads as ordinates and the values of $V^{1.75}$ as abscissas. The slopes of the lines drawn must give the values of *m* corresponding to the power, 1.75, of the velocity. Upon comparing these values of *m* with those obtained from the logarithmic plotting, it is seen that they check quite well. These values of *m* are greater or less than the values determined logarithmically, accordingly as 1.75 is greater or less than the true *n*. Taken altogether, with these values of *m*, and $n = 1.75$, we can represent closely the whole series of experiments.

The method of least squares could also be applied in getting the values of *m* and *n*. This was tried in the case of Pipe *II*, and gave a close check upon the values taken from the logarithmic sheet. The method of least squares, however, is not as convenient, and does not expose the errors which may occur.

The differences in results for two sections of the same pipe do not seem to be accounted for through differences in diameter, except in Pipes *VI*, *VIII* and *XII*, where differences were known to exist and were allowed for in the calculations. In the other pipes small differences in resistance are noted, but must be accounted for otherwise. As first used, the two experimental sections of Pipe *XV* showed very discordant results, as the table and the logarithmic plotting show. After being cleaned by drawing waste cotton through, the results were more consistent. During the cleaning a small scale of brass was drawn out, and it seems very probable that the small differences noted in other pipes may be due to similar causes.

Table No. 7 gives the values of *m* and *n* for the galvanized pipes. As shown by the logarithmic plotting, Pipe *XVIII* seems to be an exceptional pipe. Even though of smaller diameter than Pipe *XVII* the losses of head, for velocities above 2.4 ft. per second, are lower than in Pipe *XVII* for the same velocity. It will be remembered, also, that Pipe *XVIII* is the one which showed high temperature effects in the neighborhood of 40°, and that it is the only one of the galvanized pipes which had been in use before the experiments. A slight, silt-like deposit which had occurred on the inner walls was entirely insufficient to relieve the roughness. Although the galvanized pipes do not seem to give such consistent results as the brass pipes, the experiments were made with the same care.

		40	3.90	1.781	3.74		40	3.72	1.784	
	B-C	70	3.25	1.789	....					
	B-D	70	3.33	1.786	....					
XIII	A-B	70	4.25	1.788	4.11	B-C	70	4.25	1.788	
		55	4.45	1.780	4.33		55	4.45	1.780	
		40	4.70	1.748	4.61		40	4.70	1.748	
XIV	A-B	70	5.52	1.745	5.46	B-C	70	5.58	1.755	
		55	5.80	1.747	5.78		55	5.95	1.740	
		40	6.28	1.743	6.18		40	5.45	1.731	
XV	A-B	70	6.86	1.774	6.76	A-B	70	6.66	1.764	*A-B* and *B-C* in last columns before cleaning.
		55	6.71	1.768	7.05	B-C	70	7.12	1.765	
		40	7.07	1.771	7.36					
	B-C	70	6.86	1.774	....					
		55	6.71	1.768	....					
		40	7.07	1.771	....					
XVI	A-B	70	9.78	1.771	10.21	B-C	70	9.23	1.785	
		55	10.18	1.780	10.69		55	9.88	1.794	
		40	10.28	1.795	11.25					

TABLE No. 6—Brass Pipes *II* to *XVI*, Inclusive.

Values of *m* and *n*. (*m* for Head in Feet per 100.)

Pipe.	Section.	Temp. Fahr.	*m*.	*n*.	*m* from $V^{1\cdot75}$ diagrams.	Section.	Temp. Fahr.	*m*.	*n*.	
II		70°	0.252	1.749	0.253					
		55	0.267	1.748	0.268					
		40	0.282	1.750	0.282					
III	*B-D*	70	0.372	1.754	0.377	*D-F*	70°	0.375	1.750	
		55	0.386	1.767	0.400	*E-F*	70	0.357	1.776	Few points for *E-F*.
		40	0.420	1.755	0.425					
IV	*B-C*	70	0.485	1.744	0.472	*C-D*	70	0.497	1.730	
		55	0.507	1.753	0.508		55	0.525	1.741	
		40	0.545	1.744	0.550					
V	*D-E*	70	0.584	1.747	0.580	*B-D*	70	0.584	1.747	
		55	0.600	1.763	0.613	*C-D*	40	0.660	1.755	
		40	0.660	1.755	0.660					
VI	*C-E*	70	0.770	1.737	0.788	*D-E*	70	0.729	1.755	
		40	0.880	1.738	0.864	*C-D*	70	0.850	1.722	
	A-B	55	0.850	1.738	0.822	*B-C*	70	0.815	1.758	
		40	0.895	1.743	....					
VII	*A-C*	55	1.165	1.753	1.172					
		40	1.340	1.716	1.100	*B-C* }				{ All at 70° were made before pipe
	C-D	55	1.170	1.748	....	*A-C* }	70	1.11	1.744	{ was set up the second time.
		40	1.340	1.709	....	*C-D* }				
VIII	*A-B*	70	1.53	1.732	1.615	*C-D*	70	1.51	1.787	$V^{1\cdot75}$ diagram for *C-D VII* gives
		55	1.630	1.756	1.675		55	1.64	1.780	$m = 1.47$ and 1.55.
		40	1.74	1.757	1.775					
IX	*A-B*	70	2.04	1.763	2.10	*B-C*	70	2.05	1.760	
		55	2.20	1.751	2.22		55	2.22	1.749	
		40	2.42	1.740	2.36		40	2.40	1.750	
X	*A-B*	70	2.60	1.746	2.58	*B-C*	70	2.60	1.746	
		55	2.72	1.753	2.73		55	2.75	1.745	
		40	2.94	1.741	2.90		40	2.94	1.741	
XI	*A-B*	70	3.08	1.746	3.02	*B-C*	70	3.12	1.744	
		55	3.22	1.747	3.21		55	3.26	1.749	
		40	3.45	1.743	3.41		40	3.51	1.747	
XII	*A-B*	70	3.39	1.744	3.34	*C-D*	70	3.27	1.739	
		55	3.61	1.739	3.58		55	3.48	1.738	

TABLE No. 7.

GALVANIZED PIPES *XVII* TO *XXI*, INCLUSIVE. VALUES OF m AND n (m FOR HEADS IN FEET PER 100).

Pipe.	Temp. Fahr.	m.	n.
XVII		0.820	1.981
XVIII	40°	0.905	1.808
XIX	40	1.320	1.863
XX	70	1.74	1.906
	40	1.81	1.910
XXI		3.52	1.961

CRITICAL VELOCITY.

One of the most interesting features of Plate *XL*, Fig. 1, is the evidence regarding critical velocity. As might be expected, this phenomenon is most prominent on Pipe *XVI*, where the peculiar effects are evident at relatively high velocities. For low velocities, up to 2.5 ft. per second, the slope is 1, showing that the loss of head is directly proportional to the velocity. Above a velocity of 3.5 ft. the slope is about 1.78. Between these velocities there is a region where the slope gradually changes and reaches a value considerably greater than 2. The cause, as Osborne Reynolds, F. R. S., has shown* is a change in the conditions of flow.

The effect of temperature on the point at which the change takes place is well shown by Pipe *XVI*, and also in Fig. 4, which has been prepared from the observations of Hagen.† For these experiments $0.5 \frac{V^2}{2g}$ was allowed for head lost at entrance (square-edged). This may not be quite correct. The pipes were short, being 1.55, 3.57 and 3.42 ft. long, for the small, medium and larger sized pipes, respectively. Any other allowance for entry would not change the relative position of the lines to any great extent. The figure has been introduced to show the effect of temperature in the critical-velocity region, particularly for greater temperatures than the writers could obtain, and also to verify the indications of the present experiments. The principal point to be brought out is that the change takes place at higher velocities for lower temperatures.‡ The change to the power

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* *Proceedings*, Royal Society, Vol. 35, 1883.

† "Abhandlungen der Berliner Akademie," 1854.

‡ Some recent experiments substantiating this very point came to the writer's notice after this paper had been written. They are by Messrs. E. J. Coker and S. B. Clement, and a record of them appeared in the *Transactions* of the Royal Society, Series A, Vol. 201, pp. 45–61. A single brass pipe, 0.3779 in. in diameter and 6 ft. long, was used. The experiments, also, check closely the temperature factor obtained by the writer's for ordinary, or "eddy motion," flow. The range of temperatures was from 4 to 50° Cent., or 39 to 122° Fahr. The interesting point is made that the intersections of the lines for ordinary and for "stream line" flow vary as the viscosity of the water.

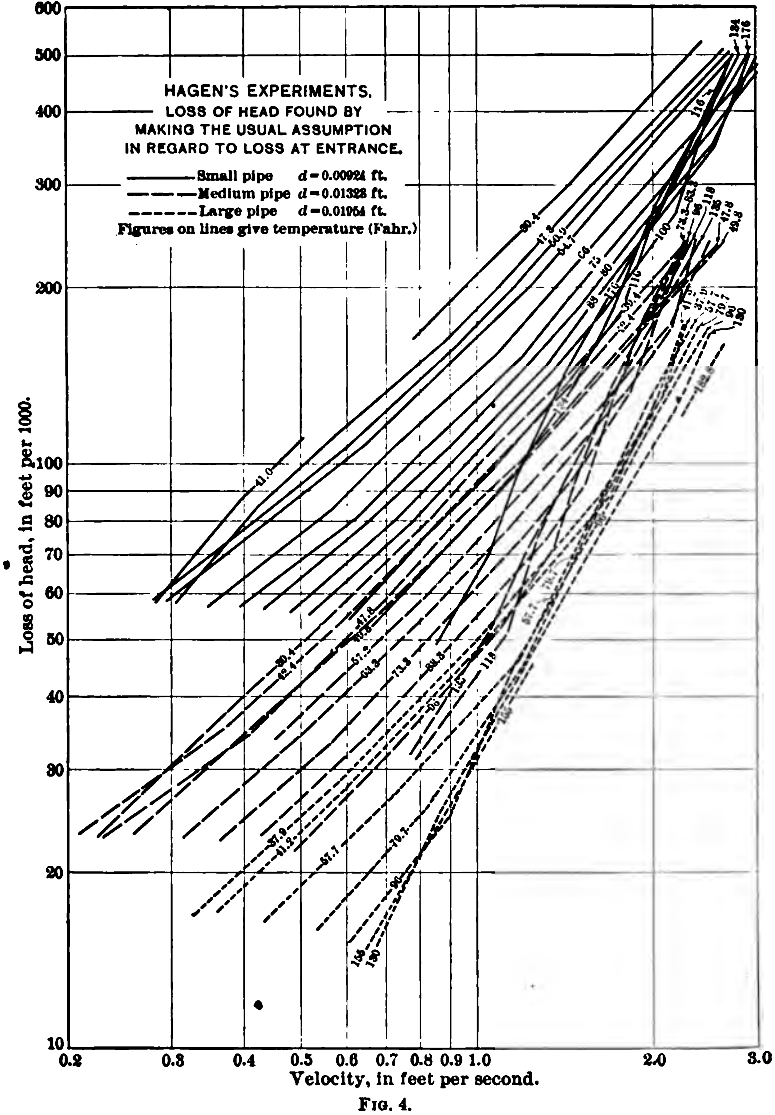
HAGEN'S EXPERIMENTS.
LOSS OF HEAD FOUND BY MAKING THE USUAL ASSUMPTION IN REGARD TO LOSS AT ENTRANCE.
Small pipe d = 0.00924 ft.
Medium pipe d = 0.01328 ft.
Large pipe d = 0.01954 ft.
Figures on lines give temperature (Fahr.)
Loss of head, in feet per 1000.
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
Velocity, in feet per second.
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
2.0
3.0

FIG. 4.

1.75, takes place on Pipe *XVI* at a velocity of 3.5 ft. at 70° and at about 5 ft. for 40°. Particular attention is also called to the crossing of the lines, and to the fact that where the loss is proportional to the first power of the velocity the difference in head for any certain temperature interval is many times greater than where the loss is proportional to the 1.75 power of the velocity. For Pipe *XVI* a line is also obtained for 75 degrees. In some pipes, Pipe *IX* for example, where two sections show very slight differences under regular conditions of flow, the differences are magnified below the critical velocity.

The interesting question, however, in connection with the critical velocity, is whether it is an element to be considered for the velocities and pipe diameters used in practice. On the basis of the experiments on brass pipe, and assuming that there is a continuity of law where extended to diameters greater than those experimented upon, the question may be given an approximate answer. The question involves the determination of the relation between the pipe diameter and the velocity at which the power of the velocity ceases to be 1.75.

On Plate *XL* the points for Pipes *XVI*, *XV*, *XIII*, *IX* and *VII*, may be determined fairly well for the experiments at approximately 70 degrees. In addition to these points, the writers have also the evidence of experiments at very low velocities on Pipe *II*. These were made early in 1901, in connection with another study in hydraulics. The heads were measured first with water and later with oil gauges. The region of critical velocity was explored thoroughly. No evidence of the phenomenon was found in the first 68 ft. of pipe down stream from the 5-in. pipe. For this section the ordinary flow equation seemed to hold, down to velocities as low as 0.25 ft. per second. But, in the succeeding length, corresponding to Section *A–B* in the present experiments, the gauges showed a decidedly unstable condition of flow from 0.55 ft. per second down to about 0.35 ft. per second. The temperature of the water for these experiments was about 40 degrees.

The critical-velocity points seem to lie approximately on a straight line. Such a line was drawn, and the intersections with the 70° lines of slope, 1.75, were marked. The velocities thus determined were then plotted logarithmically, with respect to the diameters, and from this plotting the law for impending critical velocity at 70° degrees appears to be $V = \frac{0.088}{d^{0.784}}$. This expression, being only roughly approxi-

PLATE XL.
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MAY, 1903.
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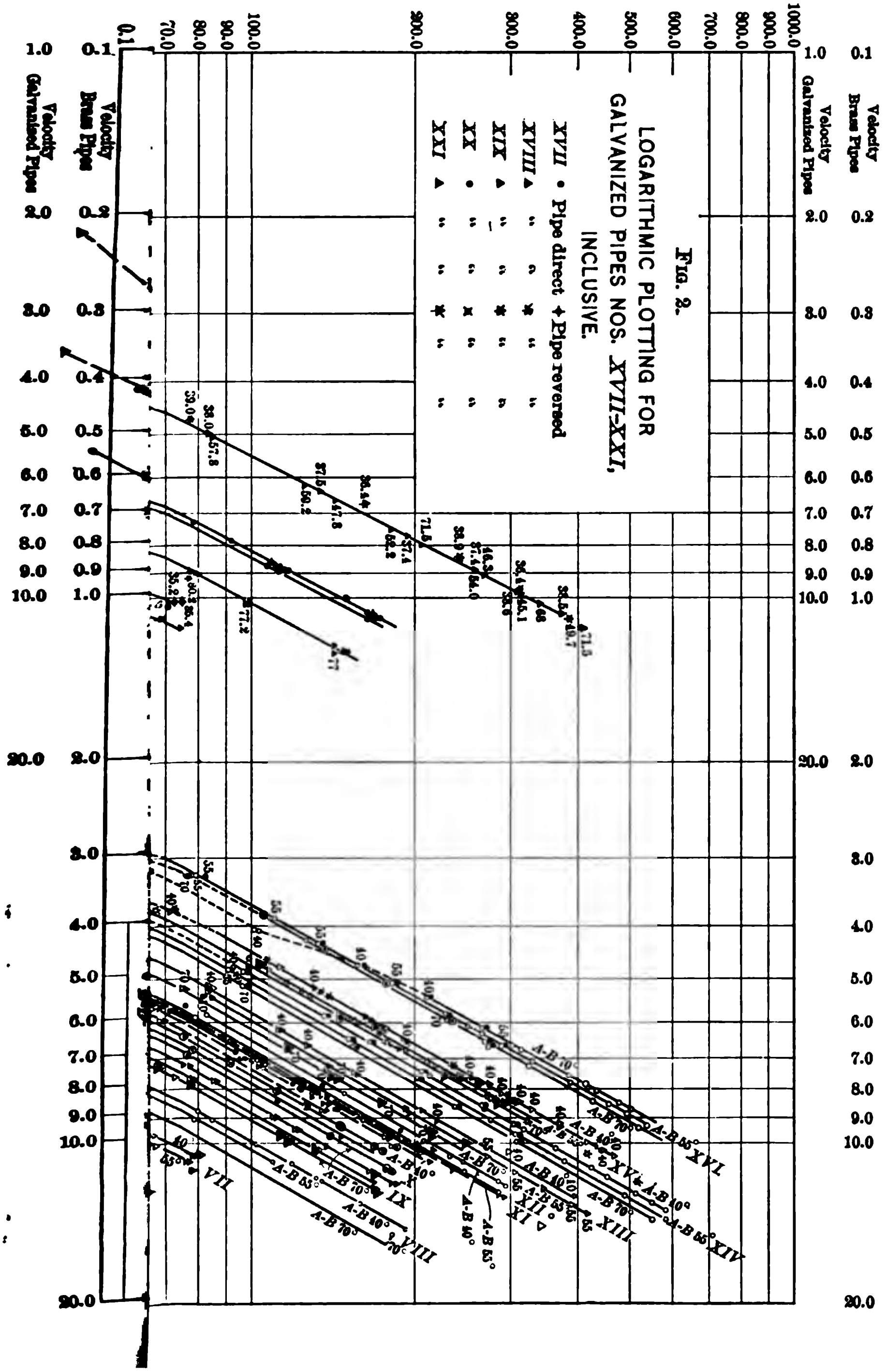

FIG. 2.
LOGARITHMIC PLOTTING FOR
GALVANIZED PIPES NOS. XVII-XXI,
INCLUSIVE.

mate, may be replaced by $V = \frac{0.1}{d^{0.75}}$ (d, in feet). For 40° there are only two points, namely, Pipes *XVI* and *II*, but these indicate the law expressed by $V = \frac{0.15}{d^{0.75}}$.

The older series of experiments do not include many with velocities below 1 ft. per second, and the critical velocity, therefore, is not easily determined. They seem to indicate, however, that the velocities at which ordinary conditions are established are somewhat lower than those given by the foregoing formula. However, it is seen from the formula that the change in condition takes place at very low velocities for ordinary sizes of pipe. Moreover, as appears from Pipe *II*, it seems that, for large sizes, a long length of straight pipe is necessary to allow the below-critical-velocity flow to adjust itself.

The formula given determines only the limiting point for the use of the power, 1.75. The lower points, where the loss ceases to be directly proportional to the velocity, are approximately on the same line that was drawn in the other case, but the intersections must now be taken with the lines of slope 1. The law seems to be about $V = \frac{0.045}{d^{0.85}}$. This law, however, is not of as much interest as the one applying to the upper points.

It seems that the question of critical velocity, while of considerable scientific interest, is of no practical importance to the engineer; but space has been given to its consideration on account of the fact that many scientists have been led astray in attempting to apply experimental data from very small pipes to pipes used by the engineer, simply because the change in the manner of flow was not understood.

EXPERIMENTS ON SMALL RUBBER HOSE.

It had been planned to perform a considerable variety of experiments on small hose, especially as regards the effect of curvature on the loss of head. Unfortunately, there was not enough time to follow out by a more extended experimental study the interesting and surprising results obtained.

The hose were fed from the bottom of the large drum, 1.135 ft. internal diameter and 2.167 ft. long, at the up-stream end of the 5-in. brass pipe. A bushing, a 1-in. short vertical nipple, a 1-in. reducer-elbow, a ¾-in. short nipple, a ¾-in. disc valve, and bushings into which the connecting nipples of the hose screwed, were the fittings, in their respective order. The valve was wide open during the experiments, the pressure being regulated by a 2-in. valve on the pipe leading into the drum. An air-chamber was attached to the top of the drum, and from this a connecting hose led to a two-column mercury gauge, one arm of which was open to the air. In all the experiments the hose were allowed to drop to the floor (about 6 ft. below the bottom of the drum) and laid straight (curve experiments excepted, of course) along it, except for an easy return curve of about 3 ft. diameter and a slow rise to the sharp downward curve at the discharge end. Thus the entry and discharge conditions were alike in all experiments. The level of the discharge end, with respect to the gauge scale, was determined. An extreme variation of 0.1 ft. might have occurred.

In Experiments Nos. 655 to 658 the hose was laid on a board and held in position in a horizontal plane by means of nails. The loops occurred at the ends of the board where the hose returned on itself. Except at the ends, the curves were semicircles alternating in direction of curvature, the radius being the same as when the hose was wound on the cylindrical drum.

The hose used were of three-ply, cotton-insertion, rubber tubing with smooth interior surfaces. The inside rubber lining was very heavy.

It has been the established idea that reversal of curvature introduces about twice as much loss of head as the same amount of continuous curvature, the length of pipe being the same in the two cases. The experiments on Hose *A* contradict this so flatly that it can only be concluded that there is something radically wrong with the hypothesis underlying the accepted notion. The small size of the hose might be regarded as a bar to the serious consideration of the results, but the experiments of John R. Freeman, M. Am. Soc. C. E., on 2.49-in. hose* are somewhat confirmatory. Mr. Freeman found that a full circle of 2 ft. radius (9.65 diameters) gave practically the same excess loss over straight hose as that given by four quadrants of the same radius, but introducing two reversals of curvature. In figures, the full circle gave $5\frac{1}{2}\%$ less excess loss.

In the curvature experiments on Hose *A*, the data of which are given in Table No. 8, the radius of curvature was $2\frac{15}{16}$ ins., or nearly eight diameters. The amount of curvature was purposely made large so that the effects might show up in no uncertain manner.

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* *Transactions*, Am. Soc. C. E., Vol. XXI.

TABLE No. 8.—Experiments on Hose.

Hose *A*. $l = 47.93$ ft. $d = 0.370$ ins.

No. of experiment.	Temp.	Total acting H, feet of water.	Loss of head, in feet per 100.		Velocity.		Remarks.
				If laid as in 647 to 650.			
647	47.5°	49.01	98.7		8.431		$0.5\frac{V^2}{2g}$ allowed for entry; 647 to 650 hose laid with two easy curves in addition to one at beginning and one at end; 659 same; 651 to 654 hose wound in a spiral of 22 complete turns around a drum of 5¼ ins. diameter; 655 to 658, 39 curves, including 3 loops; 33 reversals of curvature: curves of same radius as in 651 to 654. In curve experiments there were curves also at beginning and end as in 647 to 650.
648	....	38.14	77.0		7.343		
649	....	27.03	54.6		6.066		
650	49	14.18	28.7		4.228		
651	....	49.10	99.9	75.5	7.248		
652	49	38.14	77.6	60.0	6.371		
653	49.5	23.87	47.5	37.3	4.886		
654	51	11.23	22.9	17.9	3.241		
655	51	49.10	99.4	84.6	7.733		
656	51.2	38.14	77.3	66.6	6.760		
657	....	25.16	51.0	45.0	5.423		
658	53.0	12.34	24.9	23.6	3.692		
659	51	49.05	98.9	....	8.418		
Hose A_1. $d = 0.380$ in.							
684	49	49.09	94.8	....	7.640		$0.5\frac{V^2}{2g}$ allowed for entry.
685	49.5	34.50	66.7	....	6.307		
686	50.5	16.73	32.4	....	4.278		$l = 50.28$ ft.
678	60	49.22	47.9	....	5.488	For A_1.	Used $A + A_1$ ($l = 98.58$ ft.) and subtracted A, using a diagram based on Experiments 647 to 650.
679	61	36.63	35.4	....	4.674		
680	62.2	23.06	21.6	....	3.504		
681	63.5	8.86	8.7	....	2.108		
682	50	49.03	49.1	....	5.393		
683	42.4	74.05	73.8	....	6.787		
Hose B_1. $l = 11.87$ ft. $d = 0.504$ in.							
687	45	48.10	340.5	....	18.076		$0.5\frac{V^2}{2g}$ allowed for entry.
688	44.5	36.98	262.5	....	15.781		
689	44	24.79	176.3	....	12.854		
690	44	14.71	104.9	....	9.829		
691	44	7.85	56.8	....	7.078		
692	36.5	72.26	511.1	....	22.240		
Hose B. $d = 0.519$ in.							
693	43.5	48.80	77.1	....	7.731	For B.	Used $B_1 + B$ ($l = 61.82$ ft.) and subtracted B_1, using a diagram based on Experiments 687 to 692.
694	43	33.68	53.2	....	6.870		
695	43.5	18.77	29.9	....	4.649		
696	44	9.71	15.7	....	3.243		
697	39	74.39	116.7	....	9.728		
Hose C. $l = 14.37$ ft. $d = 0.254$ in.							
698	69	49.56	325.9	....	10.750		$0.5\frac{V^2}{2g}$ allowed for entry.
699	60.5	36.63	240.8	....	9.255		
700	58.5	24.78	162.8	....	7.520		
701	58	14.48	95.6	....	5.627		
702	58	8.17	54.1	....	4.082		
703	60	4.53	30.1	....	2.973		
704	63	49.31	324.4	....	10.757		
705	50.5	49.14	322.7	....	10.815		
706	47	48.99	321.9	....	10.750		
707	44	75.00	490.7	....	13.764		
708	43	49.81	327.2	....	11.088		

The most surprising result was, that, although each series showed a most decided effect on the loss of head and the discharge, the value of n, in the formula $H = m\ V^n$, remained practically constant, the large changes being in the value of m. (There is a small increase for the case of reversed curvature.) Should this result be confirmed by further experiments along this line, it will have an important bearing on the subject of the nature of the resistances which cause loss of head in a pipe. For it would appear that the value of the exponent, n, is determined solely by the nature of the inner surface of the pipe, while m depends on the distribution of the velocities throughout the cross-section, and on the temperature.

The fact that the reversed curves caused only about half as much increase of resistance as the continuous curves is certainly something to think about. It is to be hoped that further and more elaborate experimentation may bring out the laws which govern the resistances in various cases of flow in curves. It may not be out of place to suggest the bearing of such studies, not only on sinuous supply mains, but also on the flow in turbine wheels.

The results of the experiments on the hose when laid with easy curves and tangents are of interest in their relation to the results of the brass and galvanized pipes. The values of m and n, as obtained from a logarithmic plotting, are as follows:

Hose.	Diameter.	m, in feet per 100 ft.	n.
A	0.370 in	2.24	1.78
B	0.519 "	1.82	1.82
B_1	0.504 "	1.32	1.91
C	0.254 "	4.2	1.81

The experiments on B_1 were made with high velocities (7 to 22 ft. per second), and it is probable that the usual allowance for entry loss is insufficient, the velocities in the ¾-in. fittings being considerable. The high value of n and the low value of m bear out this statement. Hose B is free from this objection.

Especial attention is called to the low values of n for Hose A, B and C.

EXPERIMENTS ON ENTRY LOSS.

The writers made some experiments to investigate the commonly accepted value for loss of head due to a square-edged entry. The experiments were made on Pipes *II* and *X*. For Pipe *II* the cycloidal mouthpiece at the junction of the 5-in. brass pipe was replaced by a specially turned brass bushing with a plain inside face. The opening in this is 2.096 ins. in diameter, the same as Piezometers *A* and *B*. Section *A-B* of Pipe *II* was moved up stream next to the 5-in. pipe, and Piezometer *A* was inserted between the first two pipe lengths of the section. The slight ridge where the pipe was screwed up against a shoulder in the bushing was smoothed down. The entry length of Pipe *X*, likewise, was screwed into a brass bushing, giving a square-edged entry. An air-chamber was substituted for the end air-cock on top of the header, and the pressure was taken from this. The diameter of the header (2½ ins.) is so large, relatively to Pipe *X*, that practically static conditions prevailed. For Pipe *II*, however, the effect of the small velocity in the 5-in. pipe on the up-stream piezometer has been considered.

The results are given in Table No. 9. It will be seen that the values for Pipe *II* check fairly the accepted value, $0.5 \frac{V^2}{2g}$. Pipe *X*, however, gives lower indications, the values seeming to average about $\frac{1}{3} \frac{V^2}{2g}$. These results indicate the possibility of a higher value than $0.5 \frac{V^2}{2g}$ for pipes of commercial size.

EXTENT OF ENTRY DISTURBANCES IN SUCCEEDING TANGENT.

The experiments on Pipe *II* seem to show that the piezometric effects of a square-edged contraction do not extend 78 diameters down stream. Section *A-B* gives normal results. In Pipe *X*, on the other hand, Experiments 666 to 670 show that 43 diameters are not sufficient, for both the high results for entry loss and the low results for the loss in Section *A-B* show that Piezometer *A* was in the abnormal-flow region. With these results the evidence obtained by the writers on the effects of curves* should be compared.

PRACTICAL DEDUCTIONS.

The engineer will ask: "Of what use are refined laboratory experiments on pipes with conditions never met in practice?" Waiving the answer, for the present, let us examine the evidence to be had on the general subject of the flow of water in pipes.

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* *Transactions*, Am. Soc. C. E., Vol. XLVII, p. 317.

A.—Pipe *II.*

No. of experiment.	Temperature.	Observed head in water in section between Piezometer in 5-in. pipe to piezometer *A* in 2-in. pipe. Double centimeters.	Observed head in Section *A-B* in water. Double centimeters.	Loss of head due to entry, *A-B* considered normal. Double centimeters.	Velocity in Pipe *II*, in feet per second.	Remarks.
783...........	86.2°	22.89	39.92	$3.50 = 0.475 \frac{V^2}{2g}$	5.611	The up-stream section consists of 3.5 ft. of 5-in. pipe and 13.543 ft. of 2-in. pipe. Length *A-B* = 44.085 ft. Square-edged contraction. *A-B* is normal, since loss is the same as in other experiments.
784...........	86.0	16.85	29.95	2.48 = 0.454 "	4.811	
785...........	87.0	5.46	10.84	0.79 = 0.508 "	2.594	
786...........	86.8	10.61	19.40	1.50 = 0.453 "	3.761	

B.—Pipe *X.*

No. of experiment.	Temperature.	Observed head in Section Header-*A*. Double centimeters of mercury.	Observed loss of head in Section *A-B*. Double centimeters of mercury.	Loss due to entry alone, *A-B* considered normal in each case. Double centimeters of mercury.	$\frac{V^2}{2g}$ in double centimeters of mercury.	Velocity, in feet per second.	Loss in *A-B*, in feet per 100. Water.	Remarks.
660...........	54.5°	14.16	13.93	$0.71 = 0.333 \frac{V^2}{2g}$	2.13	10.628	170.7	In 660 to 665: *l* (entry) = 5.459 ft. *l* (*A-B*) = 6.719 "
661...........	56.1	21.20	20.56	1.16 = 0.348 "	3.34	13.319	252.0	
662...........	57.8	8.50	8.48	0.40 = 0.330 "	1.21	8.011	103.9	
663...........	47.8	8.60	8.64	0.40 = 0.339 "	1.18	7.924	105.9	
664...........	48.8	14.18	14.04	0.69 = 0.332 "	2.08	10.506	172.0	
665...........	50.9	5.38	5.47	0.23 = 0.324 "	0.71	6.136	67.0	
666...........	63.9	5.27	13.62	0.81 = 0.378 "	2.14	10.672	167.1	In 666 to 670: *l* (entry) = 1.144 ft. *l* (*A-B*) = 6.719 "
667...........	46.2	5.17	13.94	0.76 = 0.372 "	2.04	10.407	170.8	
668...........	48.0	3.63	9.93	0.54 = 0.386 "	1.40	8.611	121.7	
669...........	50.4	2.11	6.01	0.31 = 0.398 "	0.78	6.456	73.6	
670...........	52.0	7.94	20.38	1.22 = 0.376 "	3.25	13.150	249.7	
671...........	79.5	15.06	10.05	0.67 = 0.330 "	2.03	10.396	151.9	In 671 to 676: *l* (entry) = 6.720 ft. *l* (*A-B*) = 5.462 "
672...........	83.9	22.63	14.89	1.09 = 0.339 "	3.22	13.076	225.2	
673...........	52.8	15.44	10.45	0.68 = 0.358 "	1.90	10.047	157.6	
674...........	51.2	4.55	3.18	0.16 = 0.334 "	0.48	5.070	47.9	
675...........	51.8	9.26	6.34	0.38 = 0.352 "	1.08	7.588	95.6	
676...........	53.0	24.54	16.36	1.21 = 0.378 "	3.20	13.044	246.6	

Wherever possible, the original records of experimental data have been consulted. By the method of logarithmic plotting of losses of head with velocities, some 150 series of experiments have been investigated, and the values of m and n determined. The writers early came upon the necessity of either considering all the evidence, or else of running the risk of making errors in judgment and perhaps of allowing partiality more play than desirable in such a study.

In the preliminary plotting, all experiments which had been investigated were considered. In the final plotting many are left out. But the writers can state conscientiously that the conclusions are not altered thereby. The experiments omitted from the plotting are mostly old German and English experiments, the exact conditions and methods of measurement being generally unknown. If they were included (and the writers were sorely tempted to do so on account of the indications of most of them) they could not be given much weight, no matter what the indications, on account of this uncertainty.

Considering now the general subject, there is presented on Plate XLI a logarithmic plotting of the values of m (as determined from plottings of each series of experiments), with the diameters of the pipes. It will be noticed that the values of n are marked near the points. These serve as descriptions of the nature of the pipe, from the experimental standpoint. In addition to this, the material is also indicated. This latter is the engineer's description, and is usually far from complete, but, with the assistance of the knowledge of the value of n, the indications can be discussed more rationally.

It will be seen that the range of pipe diameters varies from $\frac{1}{10}$ in. to 12 ft. A very casual examination will show that all the points lie in a comparatively narrow zone and hence indicate some exponential relation.

First of all, the line best fitting the points for the writers' brass pipes has been drawn. On account of the very considerable effect of temperature on the value of m, the middle points, for 55°, have been used. There are plotted, also, the points for 40° and 70°, but these are not used, except to convey to the eye the magnitude of temperature effect.

The variations in the value of n for the seamless-drawn brass pipes (all apparently of the same degree of roughness), have been noted. Hence, corresponding indications due to the values of m are to be expected, and the variations from the line which has been drawn seen on Plate XLI.

One feature will be noticed at once. The line for the brass pi forms the lower limit of the zone in which all the plotted points This is another way of stating that these pipes represent the extre of smoothness and ideal conditions. The equation of this line, n lecting the third place of decimals in the exponent, is

$$m = \frac{0.296}{d^{1.25}}$$

in which m is in feet per 1 000 ft., and d is in feet. Placing this val in the general expression, $H = m\ V^n$, and using the average value n, there results

$$H = \frac{0.296}{d^{1.25}}\ V^{1.75}$$

in which H is in feet per 1 000 ft., and d is in ft. This expressio then, gives the loss of head for extremely smooth pipes laid straigh But this is not all. There occur maximum .variations in the value m of approximately 7% each way from the line of this equatio Hence, it is seen that this variation must be taken into accou There is also an effect due to the variation in n, and this may beco considerable for high velocities. It is not as prominent a factor the smooth brass pipes as in pipes used in practice, but it is point out as something to be borne in mind. The writers might wish, many hydraulic engineers have wished, that there was less uncertain in designing pipe systems, but, since it exists, its probable exte should be made an integral part of any formula. Therefore, concerni smooth brass pipes, under nearly ideal conditions, it becomes necessa to write, for the general expression,

$$H = \frac{0.296}{d^{1.25}}\ V^{1.75} \pm 7\%.$$

Looking at this, and remembering the long months of monotono experimentation, the care taken to have everything accurate, t temperature factor, which alone may cause a variation as large as th given above, the writers feel that it nevertheless represents a step advance; for while it does not tend to make hydraulic science a more exact, it at least helps to make it safer in application.

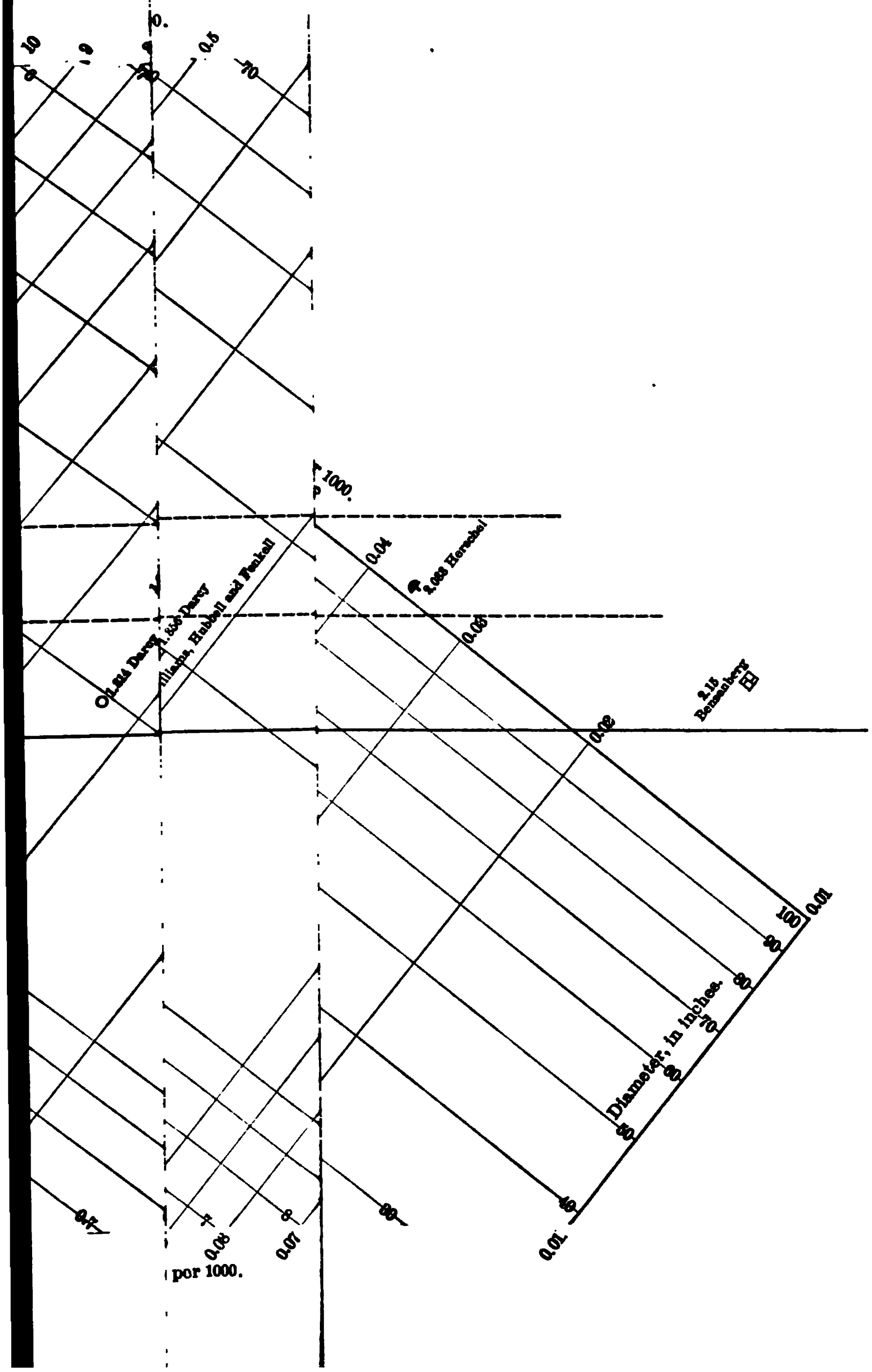
Modifying the above formula, there is obtained the expression

$$V = 104\ s^{0.57}\ d^{0.71} \pm 4\%;$$

or, using the "hydraulic mean radius,"

$$V = 279\ s^{0.57}\ R^{0.71} \pm 4\%.$$

PLATE XLI.
PAPERS, AM. SOC. C. E.
MAY, 1903.
SAPH AND SCHODER ON
FLOW OF WATER IN PIPES.



In these last expressions s is the hydraulic slope, in feet per foot of length. In these expressions temperature effect has not been included. As has been stated, the effect is to vary the loss of head about 4% for a change of 10° Fahr. Owing, however, to the uncertainty regarding the effect on the rougher pipes used in practice, the writers feel that its insertion might be misleading.

Commercial Pipes.—Considering now the kinds of pipes used in practice, the writers desire, first of all, to call attention again to the indications of their experiments on galvanized-iron pipes. It is seen that, not only is there a variation in the exponent, n, from 1.80 to 1.96, but that Pipe *XVIII*, although having but two-thirds the internal sectional area of Pipe *XVII*, nevertheless, has a decidedly greater discharging capacity per unit of sectional area, or, in other words, offers less resistance to the flow, for the same velocity. Nevertheless, to the eye, all the pipes appear to be of the same degree of roughness. These two facts throw a strong illumination on the hitherto unaccountable variations in the results of standard experiments.

Although Darcy's experiments showed clearly the effect of variations in roughness which were easily perceptible, and which could be described so as to be recognized by ordinary inspection, yet the hydraulic literature of the past decade or two bears out the statement that the extent of the effects of variations in character of surface which practically defy detection have not been appreciated. Otherwise, how can we account for statements by well-known engineers that certain formulas will give results within 2 or 3% of the truth?

Turning again to the general plotting on Plate XLI, we have to consider the experiments which lie in the zone, one of the limits of which is the line already discussed. Attention should be called to the fact that some of the series of experiments do not show much harmony in the indications, and that, therefore, it is a matter of judgment just where to draw the line on the logarithmic plotting of the losses of head and velocities. Hence, the values of m and n have the effects of the personal equation. But the two values, taken together, represent, as well as may be, the conditions in the range of the series under investigation.

It will be seen that the variations in the value of the exponent, n, are greater than the variations found by the writers for the galvanized pipes. Outside of the heavily tuberculated and riveted pipes, this variation is from 1.74 to 2.00. The exponents given for the series by Herschel and by Darcy represent fairly the point which has been made. The values of m and n for the 30-in. pipe of Williams, Hubbell and Fenkell have been furnished to the writers by Professor Williams. They are the result of a plotting of the original data, on their own merits.*

It will be seen that a line parallel to the one already drawn will represent fairly the other limit of the zone. The experiments which determine this line are those by Darcy on tuberculated, cast-iron pipe, and some of those by Herschel and some by Marx, Wing and Hoskins on riveted-steel pipe. Noble's 44-in. wood-stave pipe also comes close to this line. The equation is $m = \frac{0.687}{d^{1.25}}$. As for the general equation, we have a variation in the value of n from 1.67 to 1.99. The value, 1.67, from Herschel's 36-in. pipe, is lower than anything else on the plate. The writers consider that this value is questionable, although it is what the series of experiments gave.† Hence, the variation in n will be considered as from 1.82 to 1.99, and the general formula becomes

$$H = \frac{0.687}{d^{1.25}} V^{1.82 \text{ to } 1.99}$$

in which H is in feet per 1 000 ft., and d is in feet. Converting this into the other form, there appears

$$V = 54.7 \text{ to } 38.9\ s^{0.55 \text{ to } 0.50}\ d^{0.69 \text{ to } 0.63}.$$

Using the hydraulic radius, this becomes

$$V = 142 \text{ to } 93\ s^{0.55 \text{ to } 0.50}\ r^{0.69 \text{ to } 0.63}.$$

The two sets of equations thus far given, then, may be regarded as giving the two extremes, the first for very smooth pipes laid very straight, and the second for a considerable degree of tuberculation (or an inner surface comparable to it).

But neither one of these formulas represents the great majority of cases which confront the hydraulic engineer. These latter are included in the zone bounded by the full line and the middle line on Plate XLI. The values of n vary from 1.74 to 2.00. The equation is $m = \frac{0.296 \text{ to } 0.469}{d^{1.25}}$ and the general expression becomes

$$H = \frac{0.296 \text{ to } 0.469}{d^{1.25}} V^{1.74 \text{ to } 2.00}.$$

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* Not as described in *Transactions*, Am. Soc. C. E., Vol. XLVII, pp. 113 and 181.

† Mr. Herschel, himself, questions the reliability of seven out of eight experiments.

In the second form, this gives

$$V = 107 \text{ to } 46\, s^{0.57 \text{ to } 0.50}\, d^{0.72 \text{ to } 0.62},$$

or

$$V = 289 \text{ to } 109\, s^{0.57 \text{ to } 0.50}\, r^{0.72 \text{ to } 0.62}.$$

This last series of equations may be said to represent the range of results which the best modern experimenters have obtained on actual pipe lines in service or ready for service. The range of values is large, but the writers do not desire to narrow the analysis any more at present. Their purpose will have been accomplished if this paper serves to bring out some of the factors which have been neglected or not fully appreciated in the past. Above all, it is hoped that a vigorous discussion, in the true scientific spirit, may result, and that less of personality and more of the truth may appear than is wont to be the case.

The experiments, the data of which are given in this paper, were performed between February 24th, 1902, and February 25th, 1908. Experiments Nos. 25 to 771 were performed after July 10th, 1902 Earlier preliminary experiments, during 1901, are noted in the paper.

The original notes and the data tabulated from them are on file in the Hydraulic Laboratory of the College of Civil Engineering of Cornell University, where they are available for examination at any time.

APPENDIX.

DISCUSSION OF THEORIES.

The writers do not venture, at present, to give any hypothesis showing why the exponent for smooth pipes should be 1.75. They merely give it as an experimental fact.

There has been an attempt, however, to explain the matter by saying that the resistance is really composed of two parts, one due to the true friction on the pipe wall, and depending on the first power of the velocity, and the other due to the impacts of the particles on each other and depending on the square of the velocity. The theory states that the composition of these two parts will be equivalent to one term with the power, 1.75. The formula which expresses this idea is $H_f = xV + yV^2$, x and y being coefficients, the values of which are to be determined. Since this formula (or its many modifications) has been used extensively, and since it expresses the idea put forth above, the writers have investigated it, to see, if in this form or in any of its modified forms, it can be made to represent accurately a series of experimental results.

In order to determine the values of the coefficients x and y, at least two methods have been in vogue. The first—the method of least squares—is allowable only on condition that the coefficients are proved to be constants, otherwise the formula derived and its limits of error apply only to those experiments which are used, and its application may be limited. The second method—a graphical one—is for this reason more general, but in most cases in which it has been applied it has not been carried to completion. It consists in obtaining first a series of equations in x and y by substituting the observed values of H_f and V. These equations may be represented by straight lines, and, if x and y are constants, all these lines should pass through one point the coördinates of which are the desired values. Ordinarily, however, it is said that the lines will not pass through a point, but will enclose a small area, and in such a case the coördinates of the center of gravity of the area are the values of x and y. This method has been applied by the writers to a number of series of experiments, and in no case, if a suitable scale was used, did the lines pass through a point or enclose an area. In every case the lines formed a series of tangents to a regular curve similar to one branch of a hyperbola, and to which the axes were apparently asymptotic. This showed clearly that x and y, instead of being constants, were really functions of V. Further investigation also showed that x and y were always such functions of V that the final result was that obtained by a direct logarithmic plotting.

For example, if the logarithmic plotting leads to $H_f = m\ V^{1.75}$, this method leads to $H_f = x\ V + y\ V^2 = (a\ V^{0.75})\ V + (b\ V^{-0.25})\ V^2 = (a + b)\ V^{1.75}$. If it is admitted that $H_f = m\ V^{1.75}$ represents accurately the relation, it can also be proved mathematically that any attempt to express the relation in two terms will lead to variable coefficients and finally result in the same way as shown above.

A more general expression, $H_f = a\ V + b\ V^2 + c$, is sometimes used. It can be shown, also, that a, b and c will be functions of V. In a number of cases where this form has been used, negative values of c have resulted when a, b and c have been found by least squares. These, surely, are not easily interpreted.

The foregoing investigation shows that the explanation given for the presence of the exponent, 1.75, and which is expressed by the Prony formula, $H_f = x\ V + y\ V^2$, by those who hold to this idea, is questionable. It also shows that all formulas which involve V^2 in any way will also involve in general a coefficient depending on V. The exception consists in the fact that a very few experiments on pipes do show an exponent of 2. As is readily seen, we thus account for the variables f and c in the familiar formulas, $H = 4 f \frac{l}{d} \frac{V^2}{2g}$ and $V = C\sqrt{r\ s}$. Of all the forms yet advanced, the only one which will represent the conditions at all accurately is the one the writers have adopted, $H_f = m\ V^n$, and n is to be determined for each series of experiments. It will be seen, of course, that the formula, $V = C\ r^x\ s^y$, is merely a modification of $H_f = m\ V^n$, m being dependent on d.

The writers, for a time, had the idea that the reason for the exponent of V being different from 2 might lie in not distinguishing between the square of the mean velocity and the sum of the squares of the individual velocities throughout the cross-section of the pipe. (They fully recognized, however, the fact that the idea of flow in parallel filaments is merely a theoretical convenience.) They therefore have investigated the question as to what power of V_m will give the same result as $\frac{\Sigma\ V^2}{\pi\ r^2}$. The supposition that the velocity curve is an ellipse, led to results which indicated that their view was correct. The exponent of V_m had a value of 2 for a velocity of 8 ft. per second and decreased for lower velocities. For a velocity of 1 ft. per second, many peculiarities in the values of the exponent were shown similar to those which the present experiments show in the critical-velocity transition stage. However, the best test of theory is experiment, and when a series of Pitot tube traverses was investigated, there was found the experimental fact that the relation, $V_m^{\ 2} = \frac{\Sigma\ V^2}{\pi\ r^2}$, holds almost exactly in every case. While proving that the proposed explanation was incorrect, this fact will doubtless be of value to those who are interested in determining the true form of the velocity curve.

In connection with the value, 1.75, obtained for the exponent on brass pipes, it will doubtless be of interest to mention the fact that Hagen gives the following relation for obtaining the volume of a unit weight of water at any temperature:

$$(t - x)^{1.743} = n\ (G - y)$$

where t is the temperature, x the temperature at the greatest density, G the volume of a unit weight at the temperature t, and y that at the temperature x. The writers would not venture to say that there is any connection between this exponent, 1.743, and the exponent which they obtain for smooth pipes. The coincidence, however, is interesting.

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THEORY OF CENTRIFUGAL PUMPS AND FANS: ANALYSIS OF THEIR ACTION, WITH SUGGESTIONS FOR DESIGNS.

By Elmo G. Harris, M. Am. Soc. C. E.
To be Presented September 16th, 1903.

Introduction.

The writer recently had occasion to look for a satisfactory discussion of the theory of centrifugal pumps, and, not finding the subject introduced at all in most of the books on kindred subjects, he undertook to hunt up some special literature bearing upon it, and was surprised to find that, apparently, the subject of centrifugal pumps had been overlooked or neglected by competent writers on applied mechanics.

That this is true is a matter of no small surprise when the importance of the subject and its attractiveness, theoretically, are considered.

To those who would say that to follow out the conclusions recommended in this paper would lead to unjustifiable refinement in machines applied to rough and temporary use, the answer should be: Knowledge of correct principles does not necessitate extravagant

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Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and when finally closed, the papers, with discussion in full, will be published in *Transactions*.

refinement, but with it we can simplify and cheapen the machine in such a way as to make the least sacrifice of efficiency; and, further, that there are no apparent reasons why refinement in proportions and workmanship will not yield results fully justifying the extra cost, thus placing the machine in a higher class and extending its use to conditions now considered out of its field.

As a result of this study there are proposed three classes of pumps—Centrifugal, Impulse and Turbine. The necessity of distinguishing purely impulsive action from centrifugal force will be apparent to anyone who follows the discussion, and who has a fair knowledge of mechanics.

In the mathematical equations and formulas introduced in this study there is no attempt to include a factor or term to account for losses by friction, impact, or otherwise. Such losses will occur, of course, but they are of a nature which does not permit of mathematical formulation. The writer thinks it better to present the underlying principles clearly, with the simplest and least possible mathematics, and then interpret the results of experiment by comparison with what ought to occur under perfect conditions. With this in view, the several causes of loss are discussed, and suggestions offered for finding where the greater portion of this loss occurs. (See page 490.)

The writer has found some attempts at mathematical analysis for determining the proportions of a pump that should give maximum efficiency, but thinks that such analyses are a misuse of mathematics, and are apt to put the science in disrepute. Whatever the design of a centrifugal pump (or of an impulse pump), the dynamic principle on which it acts is that of imparting energy to water by giving it a high velocity. Within the machine, the water must be taken from a state of rest (practically), put in motion and brought to rest again, or nearly so. The problem for the designer is then, simply: To put water in motion and stop it again with the least possible friction of water on metal and of water on water—simple in statement, but not simple in accomplishment.

In taking up this study the writer had no intention of going beyond the mathematical analysis, but, was irresistibly led into attempts at designing with a view to reducing friction losses to a minimum. In these designs the novel features introduced are: First, the introduction of air instead of water between the wheel and casing; second, the support of the wheel (in some designs) by air pressure from below; third, the use of flaring nozzles for checking the velocity of the water as it leaves the propellers, whereby the energy of the velocity can be converted into pressure with the least possible loss; and, fourth, making the discharge adjustable.

With pumps designed and tested according to the conclusions of this study, it will be possible to determine satisfactory coefficients to apply to pumps of a specific class, working under specific conditions.

The proposed modifications, in construction, in proportion, and in operation, make machines so different from anything yet tried that they must be considered as designs evolved from theoretic considerations without the light of experience. Though all the theoretic results may not be realized to a satisfactory degree, the writer believes the study will result in improvements on present practice.

CENTRIFUGAL PUMPS.

Symbols.—For convenience of reference, the symbols used are collected here. The reader should not be discouraged by the formidable array; they do not all come in at once, and the working formulas will be found to be surprisingly simple. Most of the symbols are also indicated on the diagram, Fig. 1.

r = Radius of outer limit of vanes;

r_1 = Radius of inner limit of vanes;

x = Radius of any intermediate point—a variable;

u = Velocity of revolution of outer limit of vanes;

u_1 = Velocity of revolution of inner limit of vanes $= \frac{r_1}{r} u$;

V = Velocity of escaping water, relative to revolving wheel;

V_1 = Velocity of entering water, relative to revolving wheel;

v = Absolute velocity of escaping water;

v_1 = Absolute velocity of water as it enters between vanes;

W = Weight of a cubic unit (foot) of the water (or other liquid);

b = Width of vanes at outer limit = width of circumferential opening or slot through which discharge occurs;

b_1 = Width of vanes at inner limits;

a = Area of discharge slot $= 2 \pi r b$;

a_1 = Area of entrance to vanes $= 2 \pi r_1 b_1$;

Q = Quantity (cubic feet) of liquid passing (per second);

β = Angle between V and u;

θ = Angle of discharge, relative to a tangent to wheel = angle between v and u;

ϕ = Angle between v_1 and $u_1 = 90^\circ$, unless guide vanes be inserted;

h = Head, or lift, above pump;

H = Total effective lift;

k = Initial or entrance head, which is usually suction, or negative head;

p = Pressure head in space between wheel and casing = pressure head in water at instant after escape from wheel.

"Foot-pound-second" units will be used.

Purely Centrifugal Effects.—In this preliminary study the reader should disincumber his mind of the more complicated conditions under which centrifugal pumps actually work. We are now seeking the relations between velocities unaffected by change of pressure. Later, the suction and discharge pressures will be introduced.

Consider a prism of liquid, of unit area and extending between the limits r_1 and r, in a revolving wheel without outlet, as $C\,B$, Fig. 1. The centrifugal force of an elementary disk across this prism, of thickness $d\,x$ and distance x from the axis of revolution, is

$$d f = \frac{W\,u^2_x\,d\,x}{g\,x}$$

where u_x is the velocity of revolution at the distance, x, from the center. Thus

$$u_x = \frac{x}{r}\,u,$$

therefore

$$d f = \frac{W\,u^2}{g\,r^2}\,x\,d\,x,$$

and the total centrifugal force, f, which is effective at the outer end of this prism, is the integral between the limits, $x = r$ and $x = r_1$.

Hence

$$f = \frac{W\,u^2}{2\,g\,r^2}\,(r^2 - r^2_1) = \frac{W}{2g}\,(u^2 - u^2_1), \text{ since } u_1 = \frac{r_1}{r}\,u.$$

This is the pressure on a unit area at the circumference of the wheel, and, evidently, it is independent of the form or cross-section of the arm, $C\,B$. Now, pressure divided by weight gives head. Hence the pressure head against the walls of the pump at the circumference

$$= \frac{u^2 - u^2_1}{2\,g}$$

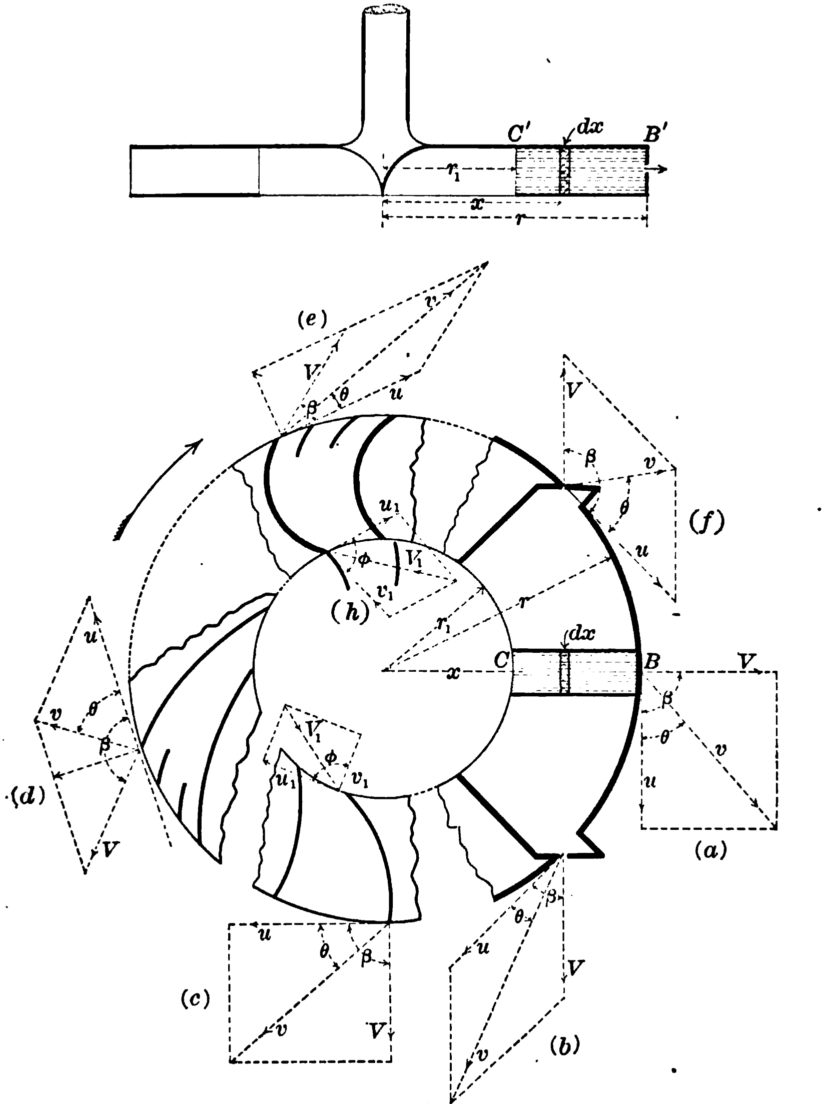
C′
dx
B′
r_1
x
r
(e)
v
V
β
θ
u
V
β
v
θ
(f)
u
u_1
φ
V_1
v_1
(h)
r_1
r
dx
C
B
x
V
β
θ
v
u
(a)
u
v
θ
β
(d)
V
V_1
φ
u_1
v_1
β
θ
u
V
(b)
v
u
θ
β
(c)
v
V

FIG. 1

Now, if an orifice be opened at the circumference, in any direction whatever, and the pressure outside be the same as at the entrance, the velocity of the discharge, relative to the revolving walls of the pump, will be

$$\sqrt{2\,g \times \text{head}},$$

or

$$V^2 = u^2 - u^2_1;$$

but when there is a discharge there must be an initial velocity, V_1, at the entrance, and this must be considered in the final head within the wheel. Thus, the total head at B will now be

$$\frac{V^2_1}{2\,g} + \frac{u^2 - u^2_1}{2\,g};$$

and the velocity of the discharge, relative to the revolving parts, will have the relation

$$V^2 = V^2_1 + u^2 - u^2_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (I)$$

Suppose, now, that $C\,B$ is a radial frictionless tube, open at both ends, and that a particle starts from a state, V_1, relative to the tube, and moves out, without change of pressure, from radius r_1 to r, in obedience to the law of centrifugal force (or acceleration). Its radial acceleration, when distant x from the center, is, by well-known laws of mechanics:

$$\text{Acceleration} = \frac{u^2_x}{x} = \frac{d\,V_x}{d\,t}.$$

Also,

$$V_x = \frac{d\,x}{d\,t}.$$

Therefore,

$$V_x\,d\,V_x = \frac{u^2_x\,d\,x}{x};$$

but, as before,

$$u_x = \frac{x}{r}\,u,$$

(sub x indicating the conditions at the distance, x, from the center.) Therefore,

$$V_x\,d\,V_x = \frac{u^2}{r^2}\,x\,d\,x.$$

Integrating between the limits, V and V_1, on one side, and, r and r_1, on the other, we get

$$V^2 - V^2_1 = u^2 - u^2_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (I)$$

Combined Centrifugal and Impulsive Effects.—In Equation I the reader will probably recognize the well-established relation of velocities in impulse water-wheels. It is demonstrated in Church's "Notes on Hydraulic Motors," and is there shown to apply to either pumps or motors as long as they act impulsively. It has not been recognized, however, as being applicable to purely centrifugal effects acting statically, as demonstrated on page 482.

The demonstrations of Equation *I* evidently apply to any liquid, and to any gas in which the density may consistently be assumed as unchanged throughout the operations. (See page 520.)

It has now been made apparent that Equation *I* will hold, whether or not the section of the channel between *C* and *B* is constant, and without regard to the direction of the discharge; that is, the discharge may be outward, inward, backward, forward, upward or downward; that it is true whether the accumulation of centrifugal effect appears as pressure alone or as velocity alone, or partly in both; and that it is true for purely impulsive effects and for combined centrifugal and impulsive effects. The formula, therefore, is much more general than has been supposed heretofore.

Absolute Velocity of Discharge.—Having now a formula for computing the velocity of the escape of water from an opening in the perimeter of a wheel, relative to the wheel, its absolute velocity can be obtained from the triangle fixed by u, V, and the included angle, β, Fig. 1.

Thus, evidently, in general,

$$v^2 = V^2 + u^2 + 2\,u\,V \cos.\,\beta \ldots\ldots\ldots\ldots\ldots \quad (II)$$

where β is the angle between V and the forward direction of u. Note that when β exceeds 90°, its cosine is minus. In particular, when $\beta = 90°$, or the vanes are radial at the outer end and $p = p_1$, then

$$v^2 = V^2 + u^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (III)$$

It is well, here, to call attention to the effect that the angle, β, has on v. Notice that u and V are constant in all the several diagrams of Fig. 1, yet v is very different in the several cases. Now, if the reader will remember that the head varies with the square of the velocity he will see that the theoretically possible head, or lift, in Case (*e*) is about six times as great as in Case (*d*). (See also page 494.)

Pressure Head in Discharge and Entrance.—The foregoing formulas for V and v are derived on the assumption that the water is discharged into a medium in which the pressure is the same as in that from which the water entered the wheel, as, for instance, atmospheric pressure within the entrance and outside of the wheel. This, evidently, is not a condition under which centrifugal pumps work ordinarily. Usually, there is "suction" inside the wheel, and, it is generally (erroneously) supposed, a pressure nearly equivalent to the remaining lift, opposing the discharge. Some relations involving this phase of the subject are as follows. See Fig. 2.

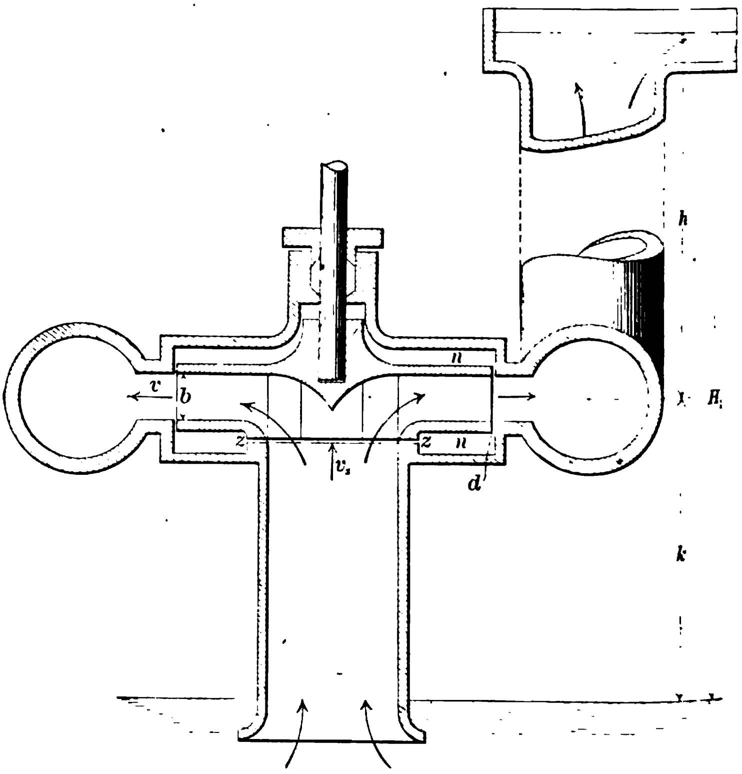

FIG. 2.

Let p_1 = pressure head at entrance of vanes, where velocity is v_1. Then

$$k = p_1 + \frac{v_1^2}{2g}.$$

Let p = pressure head in water immediately after escaping from wheel, where velocity is v, that is, at the joint, d, Fig. 2.

Then remember that whatever head, H, or lift, the wheel gives to the water, it is accomplished while passing out between the vanes.

Remember, also, that the total head in the water immediately after escaping from the wheel (that is at the joint, d) must equal the remaining lift, h.

Heads above the wheel are plus, those below are minus.

Then,

$$k + H = \frac{v^2}{2g} + p = h,$$

by the law of conservation of energy, or

$$\frac{v^2}{2g} = h - p \dots\dots\dots\dots (IV)$$

and

$$H = \frac{v^2}{2g} + p - k \dots\dots\dots\dots (V)$$

If, in Equation IV, p = zero, or atmospheric pressure, then $\frac{v^2}{2g} = h$; and if $p = k$, in quantity and in sign, then $\frac{v^2}{2g} = H$; which are evidently correct.

Note that p cannot equal h, as is usually supposed, for then v would be zero, and there would be no discharge.

Note that the signs in Equations IV and V are general, but that p and k may be, in themselves, plus or minus. Care must be taken to observe this, or confusion will result.

If possible, in practice, p_1 should equal p, for then there will be no tendency to leak at the joint, z. (See page 496.)

Notice that the pressure, p, at the joint, d, will extend throughout the spaces, n, n, between the wheel and the casing.

The question now turns on this unknown quantity, p. That it is a factor we cannot ignore, is evident, for it affects the volume of discharge, and it renders useless the formulas thus far given, unless it can be determined and controlled. (See page 490.)

The processes by which Equation I is reached are not applicable unless $p = p_1$, and has the same sign, but, fortunately, the method used on page 482 can be extended to meet the present needs.

When there are no guide vanes (and this will be the common condition), the absolute velocity of approach, v_1, will be radial, as at C, Fig. 1. In that case $V^2_1 = v^2_1 + u^2_1$.

Inserting this in Equation I, we get

$$V^2 = v^2_1 + u^2.$$

Hence the head, relative to the wheel, within itself, at the perimeter, due to centrifugal effects, independent of pressures before entering, is $\frac{v^2_1}{2g} + \frac{u^2}{2g}$. Now, if the total head at the entrance is k, the pressure head there will be $k - \frac{v^2_1}{2g}$, and the total head within the wheel at the perimeter is

$$k - \frac{v^2_1}{2g} + \frac{v^2_1}{2g} + \frac{u^2}{2g} = k + \frac{u^2}{2g}.$$

Then, if the pressure outside is p, the velocity of escape through an orifice at the perimeter in any direction is

$$V^2 = 2g\left(k + \frac{u^2}{2g} - p\right) = u^2 + 2g(k - p) \ldots\ldots (VI)$$

Note that k and p may be either positive or negative in themselves and in numerical calculations the proper sign must go with them. For instance, if they are both negative (the common condition), their signs will be reversed in Equations *IV*, *V* and *VI*.

In Equation *VI* we have a formula for V (the relative velocity) that can be used with confidence, provided we know p. More on this subject will be found on pages 498 to 501.

From Equations *II*, *V* and *VI* we can get

$$gH = u^2 + uV\cos.\beta \ldots\ldots\ldots\ldots\ldots\ldots (VII)$$

or,

$$gH = u^2, \text{ when } \beta = 90°.$$

Which shows that H is independent of k and p. It is interesting to note that $\frac{u^2}{2g}$ is usually stated to be the maximum theoretic lift, regardless of the angle, β (see page 490).

Independent Derivation of Chief Formulas.—The following independent demonstrations are interesting, and will strengthen our confidence in the conclusions otherwise reached.

If, in Fig. 1, the vanes take up the water from a state of absolute rest and discharge it at the perimeter, the whole work done by the wheel can be expressed in terms of the reaction of the escaping water on the wheel. This reaction, by well-known laws of hydro-mechanics, is $\frac{Wv}{g}$, and the component opposed to the motion is $\frac{Wv}{g}\cos.\theta$. Then the work done by the wheel in overcoming this reaction is $\frac{Wv}{g}\cos.\theta\, u$. Then, assuming the pressure opposing the discharge to be the same as before admission, the energy in the water after escape is $\frac{W v^2}{2 g}$.

Hence,

$$\frac{W v^2}{2 g} = \frac{W}{g} u \, v \cos. \theta.$$

or,

$$v = 2 \, u \cos. \theta.$$

This being true, a glance at the trigonometrical relations in Fig. 1 will show that $v = u$, and $\theta = \frac{\beta}{2}$.

The assumption, that the water is at rest until caught up by the vanes, is not correct when the water is passing through. To get an equation meeting this condition we have only to remember that the static pressures inside and outside a wheel, though different, cannot directly aid or resist its revolution, and that, in pumps, we may assume the velocity of approach, v_1, to be caused by the pump, and, therefore, its effect on the wheel is not to be considered, it being only a preliminary incident to the final discharge. Hence, the work against the reaction of the discharged water will always be the total work done by the wheel. Then, by the law of the conservation of energy, the following equation must hold:

$$W k + \frac{W v}{g} u \cos. \theta = \frac{W v^2}{2 g} + p \, W = W h \ldots\ldots \quad (a)$$

Hence,

$$2 \, u \, v \cos. \theta = v^2 + 2 \, g \, (p - k).$$

Now, insert the value of $2 \, u \, v \cos. \theta$, from the trigonometrical relation, $V^2 = u^2 + v^2 - 2 \, u \, v \cos. \theta$, and the equation reduces to

$$V^2 = u^2 + 2 \, g \, (k - p) \ldots\ldots\ldots\ldots\ldots\ldots \quad (VI)$$

which is identical with Equation *VI*, on page 488.

From Equation *a* we have $H = \frac{v^2}{2 g} + (p - k)$, since $H = h - k$ (see Fig. 2), and, by trigonometry, $v^2 = V^2 + u^2 + 2 \, u \, V \cos. \beta$. Now substitute this and the value of V^2 from Equation *VI* and we get

$$H = \frac{u^2 + u \, V \cos. \beta}{g} \ldots\ldots\ldots\ldots\ldots\ldots \quad (VII)$$

as on page 488.

It is remarkable, and to the writer quite unexpected, that Equations *VI* and *VII* show no factor involving the radial depths of the propellers, that is, the relation between r and r_1; but careful consideration of all the conditions involved will make it clear that such should be the case. On page 484 the formula, $V^2 = u^2 - u^2_1$, may be written $V^2 = u^2\left(1 - \frac{r^2_1}{r^2}\right)$, since $u_1 = \frac{r_1}{r} u$. Here, then, we find the relation between r_1 and r involved, and the analysis there given shows that it must be; but, in that case, there is, to that point, assumed no movement of water through the pump. When water flows into the pump it must be caught up by the propellers, and the velocity suddenly changed from v_1 to $\sqrt{v^2_1 + u^2_1}$. Thus it is seen that the pump must do work on the water in the act of picking it up; and this is independent of the static head (considered relatively to the wheel imparted between the limits r_1 and r. Without adhering to a strictly correct use of mechanical terms, perhaps, we may say that with a fixed r and u the head imparted by the static effect of centrifugal force decreases as r_1 increases, while the work done by impact (or reaction) in taking up the inflowing water increases with r_1; the sum of the effects in imparting energy to the departing water being constant when r_1 only varies.

Volume of Discharge.—Referring to Fig. 1, it is seen that the radial component of V is $V \sin. \beta = v \sin. \theta$, hence the volume of discharge is

$$Q = a\, V \sin. \beta = 2\, \pi\, r\, b \sin. \beta\, V. \qquad \text{(VIII)}$$

assuming a continuous opening or slot, of width, b, around the perimeter.

Evidently, the entrance to the vanes or propellers must be proportioned to comply with

$$Q = 2\, \pi\, r_1\, b_1\, v_1 \sin. \phi \qquad \text{(IX)}$$

$v_1 \sin. \phi$ is the radial component of the velocity of the water as it enters between the vanes. This will usually be assumed to be between 10 and 20 ft. Unless guide vanes are inserted, as at (h), Fig. 1, and (b), Fig. 15, the angle, ϕ, will be 90°, and Equation *IX* will become

$$Q = 2\, \pi\, r_1\, b_1\, v_1 \qquad \text{(IXa)}$$

Present Practice, in the Light of the Preceding.—The foregoing discussion, with the resulting equations, will give light on matters not heretofore generally understood (judging from correspondence, the contents of trade circulars, and the proportions of pumps as built). For instance, it is a common statement that the theoretic lift depends only on the velocity, u, of the outer limit of the propellers, and that the theoretic lift is $\frac{u^2}{2g}$. Equation *VI* shows this to be doubly in error.

True, after a wheel is built, u is the only variable affecting the lift, but, in the intelligent design of a pump, the angle, β, is an important factor.

Some writers, whose opinions are apt to be accepted without question, state that when the propellers are curved backward, as in Fig. 5, there is, in addition to purely centrifugal effects, an outward "shove," or impulse, given to the water, as it escapes, by the tips of the propellers. In making this claim, they probably forget that the water is revolving with the propellers before it reaches the end. Evidently, when the water is moving with the propeller no impulsive action can occur between them. If the outer few inches of the propellers came in contact with still water, the effect claimed would occur, and the result would be an impulse pump.

The writer can find no theoretic reason for curving the propellers backward, but rather the reverse. (See page 485.)

In several published articles which the writer has examined, prominence is given to the test for the effect of curvature of the vanes, the test being made by running the pump without discharge and measuring the resulting pressure or head by a gauge or stand-pipe, thus getting the relation between the peripheral speed and the head for differently curved vanes.* In the light of the discussion on page 482, this scheme is fallacious, for, as the propellers, of whatever form, revolve, friction will impart the motion of the liquid to that within the inner limits of the vanes, and in a few moments all the liquid, from the center out, will be revolving with the vanes. Then, as shown previously, the pressure head at the perimeter will be

$$\frac{u^2}{2g} - \frac{u^2_1}{2g} = \frac{u^2}{2g},$$

since u_1 is zero. The curve of the vanes would have nothing to do with it. Where a discharge occurs, the curvature affects the head, but not otherwise. That varying results were actually gotten, must have been due to some circulation through the open joints, d and z, around the discharge and intake.

Unfortunately, the above-mentioned experiments, as misinterpreted, have apparently verified the very common supposition that the theoretic lift of a centrifugal pump is $\frac{u^2}{2g}$. There seems to be almost universal confusion and error concerning this, and universal neglect to consider correctly the pressure at the open joint, d. Correct equations bearing on these points—Equations IV to VII—have been given, but, to clear up the confusion, let us recall the fundamental principle in hydraulics, that "total head equals velocity head plus pressure head," and apply it to the water passing the joint, *d*, after it has left the propellers. Then, using the notation elsewhere applied, the head in the water passing *d* is $\frac{v^2}{2g} + p$, and, neglecting friction, this must equal the remaining lift, *h*, or, $h = \frac{v^2}{2g} + p$.

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* *Engineering News*, August 9th, 1900; and Richards' "Centrifugal Pumps," p. 27.

Now, *v* is always greater than *u*, except when no discharge occurs. Evidently, then, we cannot consistently assume that the lift above the pump is $\frac{u^2}{2g}$, and that the pressure head, *p*, at the discharge is that due to the same lift, for that would be assuming, by the equation above, that $h = 2h$ (or more when β is less than 90°).

Suppose the pump is revolving without discharge, then the equation becomes $h = \frac{u^2}{2g} + p$, but, on measuring the head in a stand-pipe we would find it $= \frac{u^2}{2g}$, only. Still, the equation is correct. The explanation is that the velocity head, $\frac{u^2}{2g}$, in the water is not transformed into pressure head. When a discharge occurs the water passing out must lose its velocity, and, theoretically, should gain in pressure correspondingly. This subject is discussed further on page 501.

If, in Equation V, viz., $k + H = \frac{v^2}{2g} + p = h$, we substitute the value of *H* from Equation VII, we have

$$p = \frac{u^2 + u\,V \cos.\,\beta}{g} - \frac{v^2}{2g} + k.$$

Now, in centrifugal pumps, as usually constructed and operated, the absolute velocity, *v*, is but little greater than the peripheral velocity, *u*. Hence, for the purpose of illustration, we will assume $u = v$. Then the above equation becomes:

$$p = \frac{u^2}{2g} + \frac{u\,V \cos.\,\beta}{g} + k.$$

To show by example what *p* would be in an ordinary pump, assume

$u = 50$, $V = 5$, $\beta = 120$ (or $\cos.\,\beta = -0.5$), and $k = -10$.

Then, by Equation VII, $H = 74$, and therefore $h = 64$, and, by the above equation, $p = 25$.

One cause which adds to the confusion in this matter is that the efficiency of such pumps is not far from one-half, thus making the actual lift attained about one-half the theoretic lift, or

$$H = \frac{u^2 + u\ V \cos.\ \beta}{2\,g},$$

instead of

$$H = \frac{u^2 + u\ V \cos.\ \beta}{g}.$$

It is very important that the pressure, p, be measured in any test, for by its aid we can interpret results much more intelligently than has been done in the past. For instance: The lift, h, above the pump should equal $\frac{v^2}{2\,g} + p$, and the deficiency shows what is lost after the water passes the joint, d. Thus we may determine where the greatest loss occurs.

Balancing.—The much-discussed subject of balancing centrifugal pumps should be studied in the light of the preceding remarks.*

The assumption that the pressure head under the propeller disk is that due to the lift above the wheel is certainly wrong. The problem is different in every design, and, in any design, the proportions affect the results.

The following special case is interesting: The wheel, $A\ A$, Fig. 3, revolves over the fixed plane, $B\ B$, with peripheral velocity, u. The space, $C\ C$, is filled with water which revolves with A, and, by virtue of its centrifugal force, exerts a pressure downward on B and upward on A. What is the force tending to lift A?

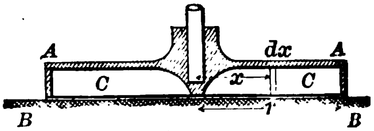

FIG. 3.

The head, at the distance, x, from the axis, is $\frac{u_x^2}{2\,g}$, where $u_x = \frac{x}{r}\,u$. The upward pressure on a ring, of radius, x, and radial width, $d\,x$, is

$$d\,p = 2\,\pi\,x\,d\,x \times W \frac{u^2\,x^2}{2\,g\,r^2} = \pi\,\frac{W\,u^2}{g\,r^2}\,x^3\,d\,x.$$

Integrating between $x = r$ and $x = 0$, we get

$$P = \frac{\pi\,r^2}{2} \times W \frac{u^2}{2\,g}$$

which is half the pressure on a circle, of radius r, due to a head of $\frac{u^2}{2g}$. This uplift is doubled in some designs proposed later herein.

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* *Engineering News*, Vol. 88, p. 75.

Form and Depth of Vanes.—According to the mathematical analysis on page 487, the ratio, $\frac{r_1}{r}$, does not affect the head under which the pump can work. Notwithstanding that, the ratio should be selected with care, in order that the pump may be otherwise proportioned conveniently and efficiently. In the light of the preceding, there are no grounds for making the outer radius, r, two or three times the inner radius, r_1, as seems to be the common practice.

Some builders state that every particle of water should pass around with the wheel at least once, and most of them accept that idea (judging by the proportions of their pumps). This is probably due to some notion that full centrifugal effect is not produced until the particle has made one revolution around the axis. The seriousness of this error in pumps, as heretofore designed, lies in the fact that, in proportioning them accordingly, the area of the surface over which the water moves at a high velocity is made much greater than necessary. While there are lacking experimental data on the friction of water passing over smooth surfaces at such velocities as occur in pumps, such facts as are known point to very serious loss due to this cause.

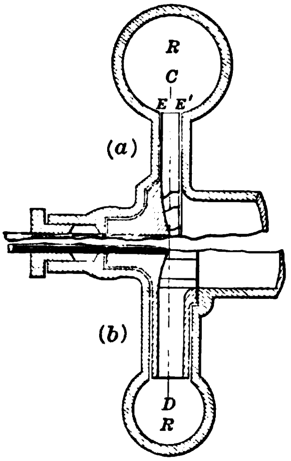
It is the writer's opinion that the less the radial depth of the propellers the better; provided that every particle of water be brought to one condition, as to pressure and velocity, before escaping from the wheel; and that the inner tips of the propellers (vanes) be set to part the approaching water without shock. It may be noted here that if the vanes be made short it becomes impracticable to make β much less than 90°, except in the special design shown in Fig. 11.

It is evident that the inner terminus of the vane is immaterial, theoretically, provided it has the proper forward inclination, as specified above. The simplest construction is that shown in Fig. 11, where the vanes are sheared off at their inner limits parallel to the axis and reaching only to the periphery of the circular inlet. If they extend to the center, as in Fig. 6, the forward inclination of the edges should vary from nothing at the center to the maximum at the outer limit of the inlet.

Influence of Discharge Passages.—Thus far, this study has been confined to the means of propulsion and its effects on the fluid. The influence of the passage which conducts the liquid from the perimeter of the propelling wheel to the final straight discharge pipe will now be studied. Here, conclusions even more interesting than in what has preceded will be found.

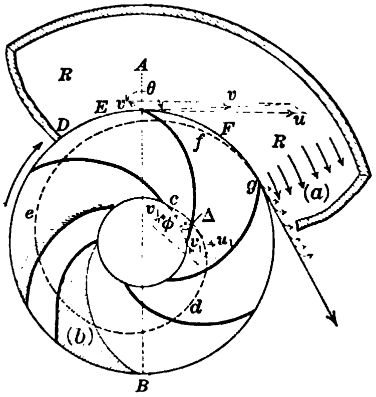
We can probably best lead up to, and understand, this part of the subject by following out the action in a pump of such proportions as are known to be common. Then modifications can be suggested.

The following data are taken from a published test of a pump made by one of the best manufacturers (unimportant fractions being omitted) (see Figs. 4 and 5):



SECTION *A-B* OF FIG. 5.

FIG. 4.



SECTION *C-D* OF FIG. 4

FIG. 5.

$r = 4$ ins.;

$r_1 = 12$ ins.;

$\beta = 153$ degrees; therefore, cos. $\beta = -0.89$;

$u = 57$ ft. per second;

$Q = 3$ cu. ft. per second;

$k = -21$ ft.;

$H = 35$ ft., as measured.

The width of the propellers is not given, but it will be assumed to be 2 ins., which will make the area of the circular inlet just equal to the area of the inlet between the propellers, that is, the water has a constant velocity of 8.6 ft. per second as it enters the wheel and passes in between the propellers.

The angle, Δ, between V_1 and u_1 is not given, but it should be 24° 15′ in order that the water may glide in without shock or break (see Fig. 7). In such wheels it is common to make the propellers of constant width. Assuming this to be so, the outlet area will be three times as great as the inlet, and the radial component of the discharge velocity, therefore, will be one-third of 8.6, or nearly 2.9. Whence, from Fig. 1, evidently

$$V = \frac{2.9}{\sin. \beta} = 6.8.$$

Then, by Equation *VII*, remembering that cos. β is minus, we get $H = 90$. As the recorded total lift was 35 ft., this would show an efficiency of 40 per cent. This does not agree with the report. However, some of the proportions have been assumed, and a glance at Fig. 5 will show the triangle involving V, u and v in a form unfavorable to accuracy.

From Equation *II*, we find $v = 51$. Then, by Equation *IV*, we have $h - p = 41$, and since $H = h - k$, and $k = -21$, h must be 69. This makes $p = 28$.

The reader must bear in mind that these are the theoretically perfect results. We know, from the results of tests, that a large part of the energy is lost somewhere.

Causes of Loss of Energy.—Now, let us discover the chief causes of loss of energy. When understood, we may then find means of avoiding, or, at least, reducing them.

(*a*)—The inner tips of the vanes should point opposite to the relative motion of the incoming water, or tan. $\phi = \frac{v_1}{u_1}$, where no guide vanes are inserted (and this will, doubtless, be the common practice), Fig. 7 (*a*). To fulfill this condition, it is evident that the discharge must vary directly with the velocity of revolution. Hair-splitting precision in this matter is not essential nor practicable, but a gross neglect will result in shock at the point of the vane and eddies just behind it. In extreme cases of neglect of this point a vacuum may occur at about (*c*), Fig. 7, especially where the suction, k, is large, Fig. 6 (*b*).

(*b*)—From the example above, we note that the radial velocity at the entrance between the vanes is 8.6 and at the discharge 2.9, the average being 5.7, while the outer tip of the vane has a velocity of 57.0. Under these conditions, the wheel makes a little more than one revolution while a particle of water passes from the inner to the outer

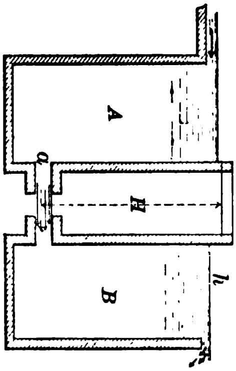


FIG. 8

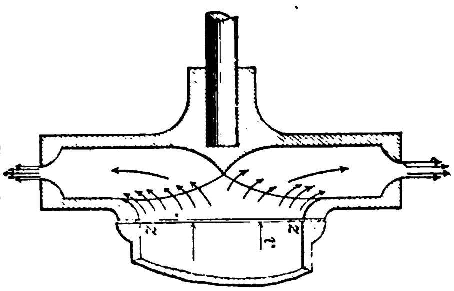


FIG. 6

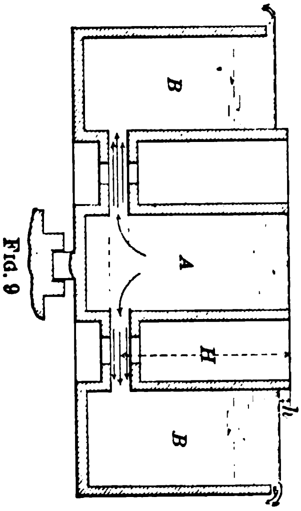


FIG. 9

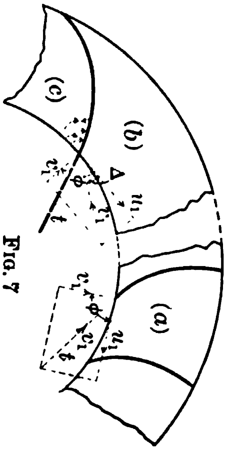


FIG. 7

limit of the vanes. During this time the water slips against the fixed sides of the casing, a distance of more than 6 ft., with a (relative) velocity varying between 19 and 57 ft. per second. This is true whether the propellers be of the open type, Fig. 4 (*a*), or the inclosed type, Fig. 4 (*b*); for, in the latter, the water surrounding the runner must either slip, relative to the runner, or relative to the fixed casing, or both. This is probably one of the chief causes of loss.

(*c*)—In the example taken we found $u = 57$. Now, if we knew all the dimensions we could compute the mean velocity in the volute, *R*, Fig. 5. It should not, and does not in practice, exceed 10 ft.

Then we would have, along the surface, *E E'*, or *D E F*, one body of water moving against another with a relative velocity of 47 ft. or more. If the wheel is of the "hollow-arm" type, that is, part of the wheel is solid, as at (*b*), Fig. 4, the last two causes will be even more serious. Here must be another important cause of loss. It is sometimes called the "drag" at the tip of the propellers. See Fig. 4 (*a*).

(*d*)—Lastly: When the section of a flowing stream is suddenly enlarged, as at *E E'*, some loss occurs.*

We have thus followed the water through the wheel, have noted the causes of loss of work, and have, to some extent, indicated the degree of importance of each. They are not of a nature that can be analyzed mathematically, but are none the less real. It should be mentioned, perhaps, that these losses depend on the construction (or design) of the wheel, its speed, discharge, etc.

The remedies for losses (*a*) and (*b*) are apparent. That under (*c*) can be reduced by decreasing the radial length of the vanes and by curving the vanes forward, thereby reducing the necessary speed. See page 490.

Losses (*d*) and (*c*) can be avoided by means now to be described.

The radical departure here proposed, in the construction of centrifugal pumps, depends chiefly on two principles, both well known, but neither, to the writer's knowledge, having been applied in this connection.†

The discharge from the vessel, *A*, Fig. 8, will enter *B* as long as the drop, *h*, is equal to the losses by friction, etc.; and the velocity of this discharge is dependent on the head *H*. Thus, without increasing the area of the orifice, *a*, or the effective head, *h*, we can increase the discharge indefinitely by increasing *H*. Now, suppose the vessel, *B*, to be continuous around *A*, and that both orifices are continuous annular slots, as in Fig. 9. Under this condition, the vessel, *A*, can be revolved about its vertical axis without interfering with the discharge or its reception in *B*. This hints at the application of the principle to increase the flow from centrifugal pumps. But a difficulty yet stands in the way: If the head in *A* is due to centrifugal effect, and that in *B* is the resulting lift, there will be closely limited relations between the rate of revolution, lift, etc., which, if changed, will result either in water not entering *B* (when the speed is too low), or in air entering with the water (when the speed is too high). To control this better, and for other reasons, apparent later, we will apply the second principle, which is that of the Sprengel Pump, or aspirator. See Fig. 10. The outwardly-flaring nozzle placed on the vessel, *B*, will cause a suction at its least section when the energy of the discharge from *A* is greater than necessary to lift the water in *B*, or against the required head. This suction will tend to exhaust the air from the space, *n*, surrounding the wheel, *l*. As the exhaustion increases (or the pressure head, *p*, drops) the discharge will increase until a state of equilibrium is reached. Then the wheel will turn in partial vacuum instead of in water, there being no leakage of air inward nor of water outward, though a clear joint is left between the wheel and the receiving nozzle, *m*. The high velocity of discharge will give an absolute direction of discharge a little less than 45° outward from a tangent when $\beta = 90$ degrees. The flaring receiving nozzle, *m*, will reduce this velocity gradually without serious loss of energy. Notice that all "thrashing" of water by impellers, and all "drag" of rapidly moving water against that which is comparatively still, are eliminated.

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* Cyclop. Brit., Vol. 12, Art. 32, p. 469.
† Cyclop. Brit., Vol. 12, Art. 28, p. 467, Fig. 36, reproduced here in Fig. 8.

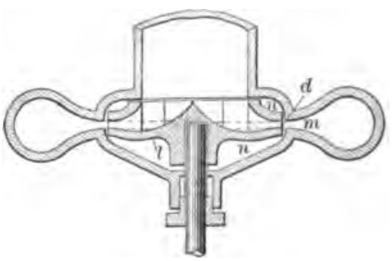
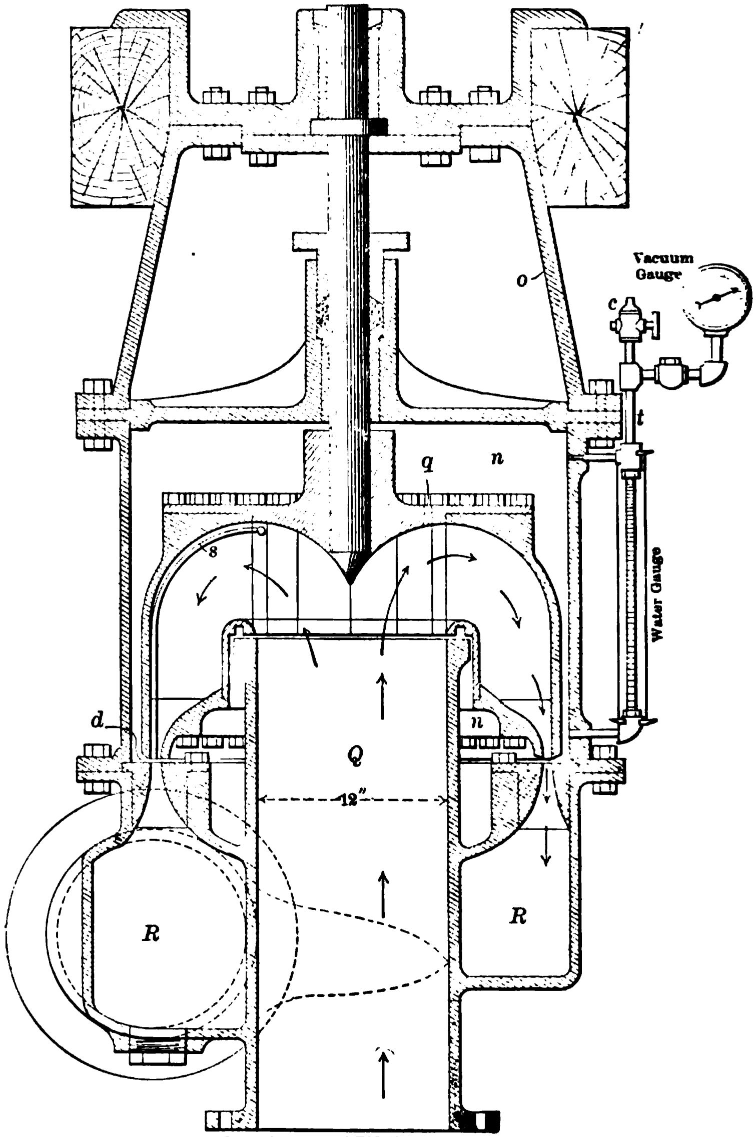


FIG. 10.

Here, then, we have a means of avoiding entirely the losses (*c*), (*d*), and (*e*) on page 498. In their place will occur whatever loss is unavoidable in the nozzle, *m*. The writer knows, from tests made by himself, that this can be reduced to 15 per cent. See page 518. In such a wheel the area of the passage through the wheel should be as large as



COMPLETE VERTICAL SECTION

Scale

0 1 2 3 4 5 6 7 8 9 10 11 12 Inches

Fig. 11.

convenient, to reduce velocity, and thereby friction loss, inside the wheel, and to give all particles time to come to one condition of pressure and velocity. The contraction for the outlet should be a sharp curve near the periphery. Note that the only sliding friction of the water against the wheel occurs in the radial movement of the water relative to the wheel. It matters not how many times the water goes around within the wheel.

The suction or minus head, p, in the space, n, probably cannot be specified until some further experimenting is done. (In some experiments of the writer with straight nozzles it was nearly 20 ins. of mercury.)

Fig. 11 presents the writer's idea of a construction well suited to secure the conditions desired, as pointed out in the preceding paragraphs.

The design shown in Fig. 11 has the further advantage that the reaction of the discharge can support the weight of the wheel partly or entirely. It has also the advantage of compactness, and the discharging and receiving nozzles can be more easily kept opposite.

Starting.—On page 491 it is shown that when a centrifugal pump is revolving without discharging, the greatest pressure head it can produce is $\frac{u^2}{2g}$, while, by Equation *VII*, the lift, when in operation, is found to be $H = \frac{u^2 + u\,V \cos.\,\beta}{g}$. Now, since the writer recommends that cos. β be always positive, or zero, it is evident that a wheel cannot start a discharge when under back pressure, from the maximum lift under which it can work after being started. This difficulty is overcome readily by putting a check-valve in the discharge, and between that and the pump a valved branch through which the discharge can be made temporarily under low head. Then, when the pump gets its normal speed and discharge, the starting valve, f, Fig. 12, can be closed gradually, and the flow will be directed into the main pipe.

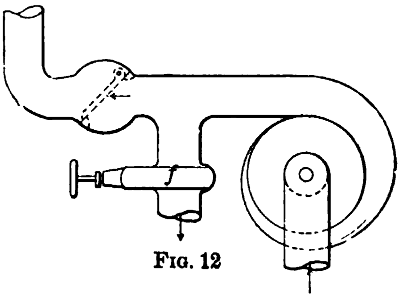


FIG. 12

In case the greater part of the total lift, H, is in suction, that is, when k is negative and nearly equal to H, numerically, the branch pipe carrying the valve, *f*, should descend into the sump, or source from which the water is taken. That this is necessary will appear from an examination of Equations *VI* and *VII*.

$$V^2 = u^2 + 2\,g\,(k - p)$$

and

$$g\,H = u^2,\ (\beta \text{ assumed } 90^\circ).$$

From these we get

$$V^2 = g\,(H + 2\,k - 2\,p).$$

Now, if k is negative and greater than half of H, and p is zero or any positive quantity, the second member becomes negative, or V indeterminate. Evidently, when k is negative and nearly equal to H, p must also be negative and greater than half of H. The arrangement specified above will insure these conditions at starting. After starting, p can be controlled through the cock, *c*, Fig. 11.

In Fig. 11, a small tube, *s*, starts from within the inner limits of the vanes and extends out to the discharge. The necessity and duty of these tubes will be apparent from the following:

If a vessel containing water and air revolves rapidly, centrifugal force will separate the two (independently of gravity), the lighter air being forced to collect about the axis of revolution. This will occur should air by any means get into any of the centrifugal pumps proportioned as in Fig. 11 (where the outlet is very much contracted as compared with the area of the passage through the wheel). The above will not hold, however, in a tube of constant cross-section leading away from the axis of revolution and open at the outer end, as the tube, *s*. On the contrary, there will be, in such a tube, a suction throughout its length due to the accelerated outward velocity of whatever water or air may be in the tube. This suction, being greatest at the inner end of the tube, will take out all bubbles that would otherwise collect about the center of the wheel and interfere with the action.

A close analogy to the above principle may be found in the suction caused by water flowing down an open vertical tube.

If, in practice, the suction, p, in the space, *n*, is found greater than k, the same purpose could be accomplished by a small hole in the top of the wheel, as at *q*, Fig. 11.

Method of Proportioning.—The formulas necessary in designing are:

$$V^2 = u^2 + 2\,g\,(k - p) \quad \dots\dots\dots\dots \quad (VI)$$

$$H = \frac{u^2 + u\,V \cos.\,\beta}{g} \quad \dots\dots\dots\dots \quad (VII)$$

$$Q = 2\,\pi\,r\,b\,V \sin.\,\beta \quad \dots\dots\dots\dots \quad (VIII)$$

$$Q = 2\,\pi\,r_1\,b_1\,v_1 \sin.\,\phi \quad \dots\dots\dots\dots \quad (IX)$$

These must be applied intelligently in order to work out the dimensions of the principal parts of a pump. The fixed conditions will usually be H, Q and k; p can be assumed with practical accuracy after some experimenting. For reasons heretofore given (pages 488 and 496), it ought to be, and probably will be, nearly equal to k. Then, until experiments give more reliable information, we may assume $p = k$. For reasons of simplicity and economy of construction, it is probable that the outer tip of the propelling vanes will be made radial, that is, $\beta = 90$ degrees. For the same reason, it is probable that the guide vanes at the entrance will be omitted, that is, $\phi = 90$ degrees.

With these simplifications the several formulas become:

$$V^2 = u^2 + 2\,g\,(k - p) \quad \dots\dots\dots\dots \quad (VI)$$

$$H = \frac{u^2}{g} \quad \dots\dots\dots\dots \quad (VIIa)$$

$$Q = 2\,\pi\,r\,b\,V \quad \dots\dots\dots\dots \quad (VIIIa)$$

$$Q = 2\,\pi\,r_1\,b_1\,v_1 \quad \dots\dots\dots\dots \quad (IXa)$$

The working out of proper proportions will now seem simple, but a difficulty will be found, in that b will in many cases be embarrassingly small. This fact alone will prevent the application of such pumps where the lift is great and the quantity small. (Modifications to overcome this difficulty are described on page 514.)

The most rational order of proceeding will be to assume a velocity through the intake channel, v_2, and also the velocity of entrance to the vane, v_1. These may both be taken safely at 10 ft. per second. As soon as the velocity through the intake is fixed, r_1 becomes known, from the condition, $\pi\,r^2_1 \times$ velocity $= Q$, for a single intake; or $2\,\pi\,r^2_1 \times$ velocity $= Q$, for a double intake. We can then find b_1 from Equation IX. Next, assume $\frac{r_1}{r}$ between 0.50 and 0.75. This will fix r. u will be found from Equation VII, V (relative velocity), from Equation VI, and b from Equation $VIII$.

Before leaving the subject of centrifugal pumps, attention should be called to the advantage of making both the discharging and receiving nozzles detachable. Then, with a few standard sizes of wheels and casings, nozzles can be attached, to meet any ordinary requirements, thus reducing the cost of manufacture; it is further desirable, on account of the liability of the nozzle to wear, especially if the water is at all gritty.

IMPULSE PUMPS.

The name "impulse pump" is given by the writer to that class of rotary pumps in which the energy is imparted to the water by impulsive action. They must be placed in a class by themselves, for, though resembling centrifugal pumps in some points of construction and in their mathematical formulas, they are quite different in principle, and present another set of problems for solution. It is sometimes said that such pumps are the reverse of the impulse water-wheel. That is true, as to principle, but an impulse water-wheel turned backward would not make a pump.

To show that the action is independent of centrifugal force, suppose the vanes, *W W*, Figs. 13 and 14, to move forward in a straight line. Then there could be no centrifugal force, and yet the water would be caught up and thrown out at the upper edge with a velocity, *v*, as shown in the figures.

In practice, the vanes must be placed on the periphery of a wheel. Fig. 15, and, if the discharge is outward, it is apt to be mistaken for a centrifugal pump. In fact, in that case, there will unavoidably be some centrifugal effect; but, if proportioned to get the best results from impulsive effect, the centrifugal effect will be relatively small. If the vanes are set to move the water parallel to the axis, as in Fig. 16, there can be no centrifugal effects. The vanes may even be set to throw the water inward toward the axis.

Careful attention should be given to the following distinctive conditions in purely impulse pumps, viz.: There should be no change of pressure in the fluid as it passes out between the vanes, the energy imparted to the fluid appearing as increase of velocity alone. That this is true will appear on inspection of Fig. 13 (*b*), where the vane is only partly filled, the water being under atmospheric pressure throughout; yet as much energy will be imparted to the water in Case (*b*) as when the space between the vanes is filled. To meet this condition requires that the area of the passage between the vanes be proportioned carefully throughout. This is not necessary in centrifugal

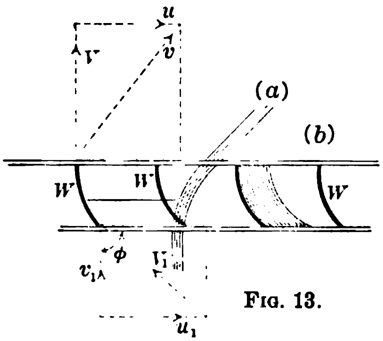


Fig. 13.

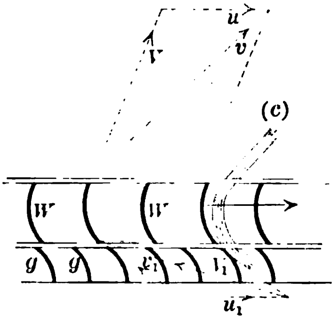


Fig. 14.

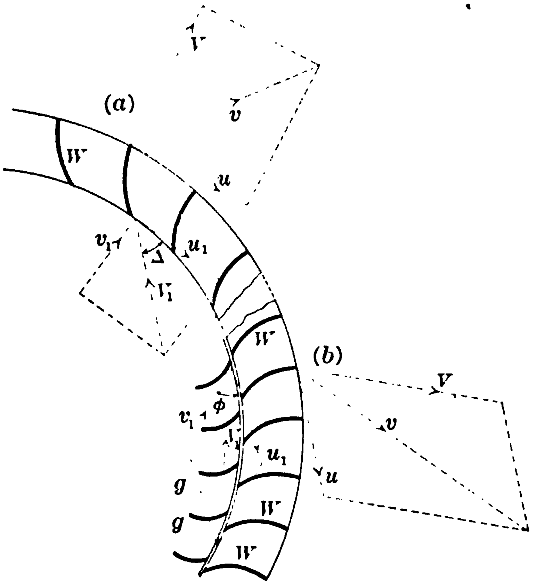


Fig. 15.

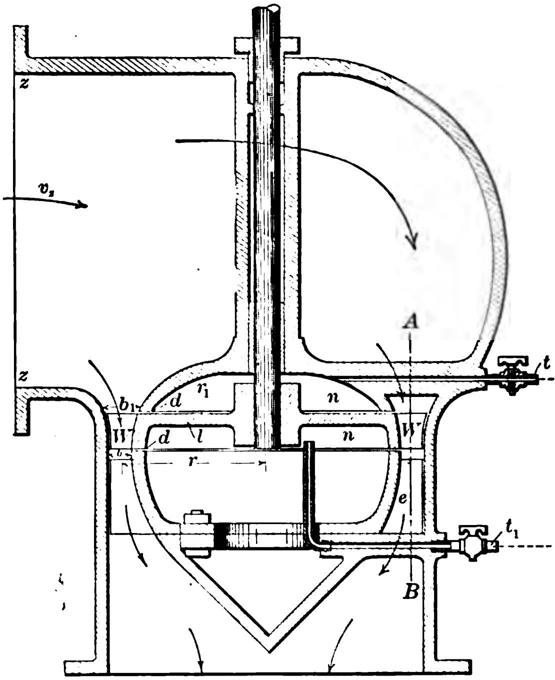
pumps. It may be said here that purely centrifugal pumps are not likely to be attempted in practice. (See page 510.)

Formulas Relating to Impulse Pumps.—Consider first the general case of an outward-flow pump with guide vane, Fig. 15 (*b*). Then, using the symbols heretofore applied to centrifugal pumps, we have at the entrance

$$V^2_1 = v^2_1 + u^2_1 + 2\,u_1\,v_1 \cos.\ \phi \ldots\ldots\ \ldots\ldots\ldots (X)$$

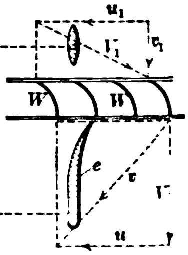
Equation *I* applies to this case. Hence

$$V^2 = V^2_1 + u^2 - u^2_1 \ldots\ldots\ldots\ldots\ldots\ \ldots\ldots\ldots (I)$$



PARALLEL-FLOW IMPULSE PUMP.

FIG. 16



SECTION *A-B* OF FIG. 16.

FIG. 17

and at the discharge we have, as in centrifugal pumps,

$$v^2 = V^2 + u^2 + 2\,u\,V \cos.\ \beta \ldots\ldots\ldots\ldots\ \ldots (II)$$

These formulas are general, from a theoretic point of view. They show that to get the greatest lift, $\frac{v^2}{2\,g}$, with a fixed u and v_1, the angles, ϕ and β, should be as small as possible; but, from a more practical point of view, there are sharp limitations to this. Notice that the length of the vanes is not involved in the foregoing formulas. Remember, also, that to reduce friction losses, the surface over which the water passes at a high velocity should be the least possible, consistent with other requirements. For this reason it will probably be found best to make the vanes short, even at the sacrifice of some of the curvature. Furthermore, the construction will be simplified and cheapened by omitting the guide vanes, *g*, *g*. Then ϕ becomes 90 degrees. For similar reasons, β will usually be 90 degrees. Under these conditions, substituting from Equations *X* and *I*, since cos. ϕ and cos. β are both zero, Equation *II* becomes

$$v^2 = 2\,u^2 + v_1^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (XI)$$

The same reasoning and the same formulas will apply where the flow is parallel to the axis, as in Fig. 16. In this case, $u_1 = u$, and therefore $V_1 \doteq V$. This is also evident on inspection.

By the law of hydraulics, that velocity head plus pressure head = total head:

$$p + \frac{v_1^2}{2\,g} = k \ldots\ldots\ldots\ldots\ldots\ldots\ldots (XII)$$

Notice that p reaches the entrance vanes, for there is no change of pressure; and, since the head, H, must be imparted to the water while it passes between the vanes, we have, by the law of conservation of energy, neglecting the velocity in the discharge main,

$$k + H = \frac{v^2}{2\,g} + p = h;$$

then, taking the equivalent of $k - p$ from Equation *XII*,

$$H = \frac{v^2}{2\,g} - (k - p) = \frac{v^2 - v_1^2}{2\,g} \ldots\ldots\ldots\ldots (XIII)$$

In this case k can never equal p, for, if it did, v_1 would be zero, and no work would be done.

Remember that when p and k represent suction they are in themselves minus, independently of the signs of the equation.

If in Equation *XIII*, which is general, we substitute the special value of v^2 from Equation *XI* we get

$$u^2 = g\,H \ldots\ldots\ldots\ldots\ldots\ldots\ldots (XIV)$$

Notice that Equations *XI* and *XIII* should not be applied except under the conditions specified in deriving Equation *XI*. These conditions, however, will be common ones in practice.

Suction Head in Air-Chamber.—On page 504 it is stated that the pressure should not change while the water is passing out between the vanes. The pressure which actually exists is p; that fixed by the suction in the throat, m. (The remarks on page 498 apply in this case as well as in centrifugal pumps.) In this case the pressure, p, reaches the entrance to the vanes, and, by Equation *XII*, v_1 depends on p; k being assumed as fixed. Theoretically, $p = h - \frac{v^2}{2g}$ (neglecting friction and velocity in the discharge pipe). If, in this case, we substitute the value of v^2 from Equation *XI*, and then the value of v^2_1 from Equation *XIII*, we get

$$u^2 = g\,(h + k - 2p) \qquad (XV)$$

If Equations *XIV* and *XV* are found to be inconsistent, the former should have precedence. Notice that p does not affect the lift, H, but does affect the discharge by its influence on v_1.

It appears, then, that until we have some experimental data concerning p, the discharge of such pumps cannot be predicted accurately. Equations *VI*, *VII*, *VIII* and *IX* apply also to impulse pumps.

Areas of Passage Between Vanes.—Theoretically, we would get the same impulsive effect if the space between the vanes were only partly filled, as in Fig. 13 (*b*); but, to avoid all possibility of spraying, shocks, or sudden change of velocity, it is necessary that the water occupy the whole volume of the interior of the wheel, and issue therefrom in one unbroken sheet of uniform velocity around the circumference. In order that this condition be satisfied, and also that there be no change of pressure in the passage, it is necessary that the areas be proportioned carefully. Using the same symbols, and assuming that there are guide vanes at the entrance, in Fig. 14 (b), we have, since v_1 sin. ϕ is the radial component of the velocity at the entrance,

$$v_1 \text{ sin. } \phi \times 2\,\pi\,r_1\,b_1 = Q \qquad (IX)$$

Whence we get b_1. Similarly, at the exit we have for the radial component: V sin. β, or v sin. θ.

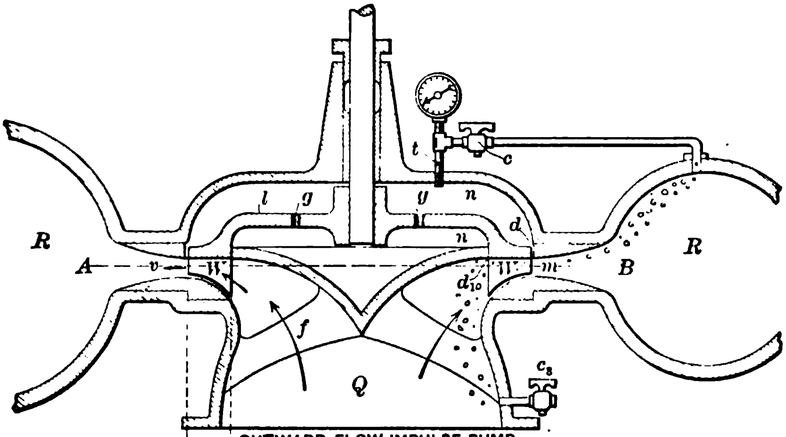
Hence,

$$V \text{ sin. } \beta \times 2\,\pi\,r\,b = Q \qquad (VIII)$$

Whence we get b.

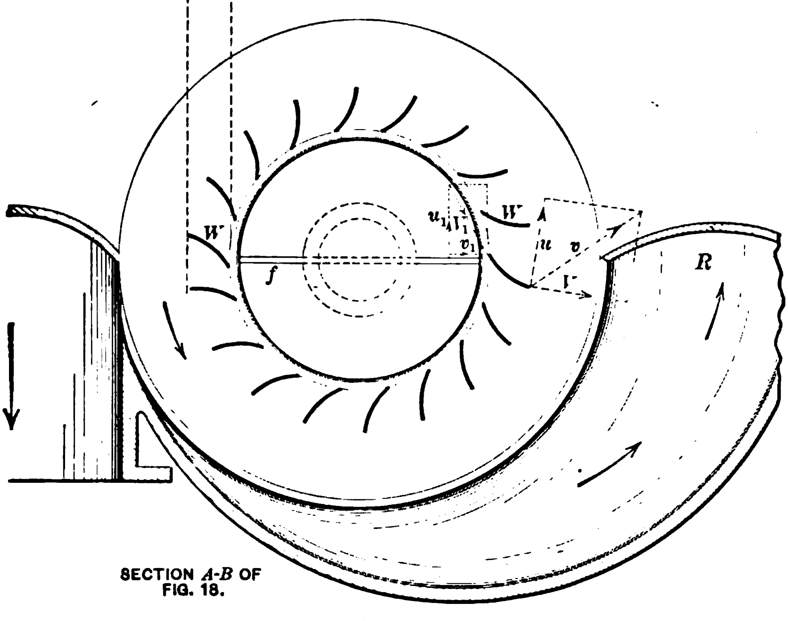
Evidently, in these, we assume that the vanes begin and end in a knife-edge. At any intermediate section of the passage the thickness of the vanes must be considered. The relative velocity at any intermediate section can be found by Equation *I*, viz.,

$$V^2_a = V^2_1 + u^2_a - u^2_1,$$



OUTWARD-FLOW IMPULSE PUMP.

FIG. 18.



SECTION *A-B* OF FIG. 18.

FIG. 19.

and the radial component is always

$$R_a = V_a \sin. \beta_a;$$

and

$$R_a\,(2\,\pi\,r_a - n\,t)\,b_a = Q.$$

Whence b_a.

The subscript, a, indicates the intermediate section; n = number of vanes in the pump, and t = thickness of the vane at the point, a. This refinement need never be applied in practice.

There is no apparent mechanical principle, or practical difficulty, that would prevent the combination of centrifugal and impulsive effects. In that case the areas of the passageway need not be proportioned as carefully; but, on the other hand, since the pressures at the entrance and the discharge to the vanes would no longer necessarily be equal, the wheel, disk, or web, should be made solid, and air admitted to the opposite sides by separate tubes, as at t and t_1, in Fig. 16; otherwise the web of the wheel can be perforated as at q, in Fig. 18, and the pipe, t_1, omitted.

Proportioning.—For convenience, the necessary general formulas for designing impulse pumps are here reprinted:

$$V^2_1 = v^2_1 + u^2_1 + 2\,v_1\,u_1 \cos.\,\phi \qquad (X)$$

$$V^2 = V^2_1 + u^2 - u^2_1 \qquad (I)$$

$$v^2 = V^2 + u^2 + 2\,u\,V \cos.\,\beta \qquad (II)$$

$$H = \frac{v^2 - v^2_1}{2\,g} \qquad (XIII)$$

$$Q = 2\,\pi\,r_1\,b_1\,v_1 \sin.\,\phi \qquad (IX)$$

$$Q = 2\,\pi\,r\,b\,V \sin.\,\beta \qquad (VIII)$$

In parallel-flow pumps, r_1 must be taken as the radius to the center line of the inlet, and r that to the center line of the outlet to the vanes, and b_1 and b are the widths of the vanes, radially, at the inlet and outlet, respectively. See Fig. 16.

When ϕ and β are both 90 degrees:

$$v^2 = 2\,u^2 + v^2_1 \qquad (XI)$$

$$u^2 = g\,H = \frac{v^2 - v^2_1}{2} \qquad (XIV)$$

$$Q = 2\,\pi\,r_1\,b_1\,v_1 \qquad (IXa)$$

$$Q = 2\,\pi\,r\,b\,V \qquad (VIIIa)$$

The order of proceeding, to get the chief dimensions of an outward-flow impulse pump, would be about as follows: Q and H being given, k will be determined by considerations of convenience. The diameter of the entrance to the wheel will be fixed by the permissible velocity at the entrance, which may be 10 ft. or less; say v_z. Then $\pi r^2_z v_z = Q$, if the inlet is on one side only, or $2 \pi r_z v_z = Q$, if on both sides. Thence, r_z. Then r_1 of the equations for the outward-flow pump should be a little greater than r_z, in order to provide a short curved approach to the vanes.

Next, we must decide on v_1. This depends on p, which is a matter of some uncertainty until some experimental data are collected. See page 508. For the present discussion v_1 will be assumed as determined. Then b_1 is obtained from Equations *IX* or *IXa*.

The outer radius, r, may be fixed by considerations of convenience of construction, and whatever light experience throws on the subject. Undoubtedly, the vanes should be as short as possible, consistent with other necessary conditions. When a length of vane is thus fixed the next step should be to find a corresponding value of u that will give the necessary head. Unfortunately, the direct determination of u from Equations *X*, *I*, *II* and *XIII*, when H, v, β, and ϕ are given, is a difficult problem. For a single computation it would be easier to assume values of u and compute H, until, by trial, a sufficiently close value of u is found. If much work of this kind has to be done, tables should be prepared showing the relations between u and H for such values of β and ϕ as may be put in common use.

When u is determined, V can be obtained from Equations *X* and *I*, and then b can be found from Equation *VIII*.

Should it be determined to make the pump without guides, and to make $\beta = 90°$, then special Equations *XI*, *XIV*, *IXa* and *VIIIa* enable us to proceed directly.

The fixed vanes, e, are to stop the revolution of the water and direct it along the discharge pipe. Three such vanes should suffice.

The reaction, R, parallel to the axis, due to the discharge of the water from the wheel, will be, from the well-known laws of reaction:

$$\frac{WV}{g} \text{ or } \frac{10 \times 62.5 \times 58}{32} = 1\,130, \text{nearly.}$$

In the method by which Equation *I* is obtained for impulse pumps and motors, the analysis follows a single particle. This, of course, is not the actual condition, and the writer suspects that, in impulse pumps, and water-motors especially, the difference between the actual and assumed conditions leads to serious errors. To explain: Suppose the vane, *d e f*, Fig. 20, to move with the velocity, *u*; our analysis assumes only one thin lamina of particles following the surface of the vane, but, in practice, there would be a considerable depth normal to the vane, and each lamina is deflected by pressure (or reaction) from the next one beneath. Thus the lamina against the vane must be under greater pressure than the outer one, and where the water reaches the discharge line, *d a*, that at *d* will escape with greater velocity than that at *a*.

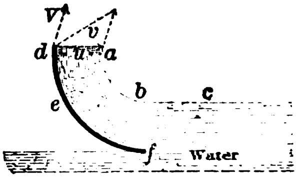


Fig. 20.

It appears that the above circumstance will make our formulas for impulse pumps unreliable, and it must also reduce the efficiency seriously, for there must be considerable loss by friction when the laminæ of water move with high and low velocities side by side.

The best remedy the writer can suggest is to increase the number of vanes, to divide the water into thin laminæ, until the advantage thus gained is lost by increase of surface friction. Further discussion on this point will be found on page 517.

The foregoing discussion will not apply to centrifugal pumps, properly so called, for there the area of passage should be so large that, by thus reducing the velocity, all the liquid is brought to one condition as to pressure and velocity before escaping. See page 494.

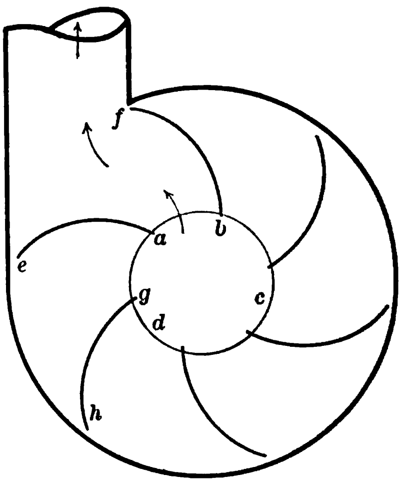


Fig. 21.

Fig. 21 shows diagrammatically what Mr. J. Richards calls an impulse pump. The writer is unable to see in it any advantage justifying its existence, but rather the contrary. One extraordinary condition in this design is that the flow between the propellers is not continuous. A glance at the figure will show that the discharge, during the instant in which any two propellers occupy the positions, *a e* and *bf*, is limited to the channel, *ab–ef*, and the velocity through *a b* must be high. The next instant, when *e* passes *f*, the outward motion of the water in *e a b f* must be stopped, and, in the same time, that in *h g a e* must be given the outward motion. It is, indeed, a thing of impulses. Surely such conditions are not favorable to smooth working and high efficiency.

Empirical Coefficients.—In all that has preceded, perfect efficiencies have been assumed, in order to present the underlying principle clearly. Every reader knows that results computed by the various formulas cannot be realized in full. Experience alone can supply the coefficients necessary to make them sufficiently correct for practice. Until some experiments are available the following may give some light on this matter:

After a wheel is built, as the lift depends only on the peripheral velocity, *u*, by computing *u* for a head greater than that specified, allowance can be made for imperfect efficiency. For instance, if the efficiency in lift is known to be 75%, and *u* is computed for $\frac{4}{3} H$, we will get the head required.

In the matter of discharge, it is known that the coefficient of discharge from well-rounded nozzles is very nearly unity. Hence, it is probable that the equation for fixing the dimensions of the passage will give results which are nearly correct when the approaches are rounded properly.

Practical Limitations.—A little inspection of the equations, and the solution of a few numerical examples, will reveal the unfortunate fact that these pumps, either centrifugal or impulse, in which the pressure in the air-chamber is below that of the atmosphere, are not applicable when the quantity of water to be pumped is small, while the head is high; the reason being that the width of the peripheral discharge slot becomes impracticably small. Just where this limit will be drawn in practice the writer will not undertake to say. See page 514.

Example.—Proportion a pump to lift 20 cu. ft. per second through 10 ft.

Let the entering velocity to the wheel, $v_x = 15$ ft., and to the vanes, $v_1 = 10$ ft.; then the area of the circular entrance must be 1.33 sq. ft., or the diameter nearly 15½ ins.

Now, if we make $r_1 = 9$ ins., it will give 1¼ ins. for curving the approach to the vanes. Then, by Equation *IX*, b_1 is found to be nearly 5 ins. If ten vanes are put in they will be nearly 5½ ins. apart at the entrance. If they are made 4 ins. deep, radially, r becomes 13 ins. Then, by Equation *VIIa*, it is found that $u^2 = 320$, or u should be about 18 ft. per second, or about 2.6 revolutions per second. From Equation *VI* (assuming $k = p$), $V = 18$, nearly, and from Equation *VIIIa*, b $= 0.2$ ft., or nearly 2½ ins.

Evidently, then, such a pump would pass any solid in which the greatest dimension does not exceed 2½ ins. It may be worth while to notice that, should any solid, too large to pass, get into the pump, it will cause no break nor even a grinding on any surface, but will merely lodge in the wheel and turn with it.

It is stated, on page 503, that in proportioning pumps to work as there assumed, the width, b, of the annular discharge slot would sometimes be found impracticably small; and, for that reason alone, the scheme could not be applied in cases where the quantity required is small and the lift great, as compared with conditions under which centrifugal pumps usually work. This difficulty can be overcome by devices now to be described.

The chief purpose now in view is to surround the propelling wheel with air at a pressure above that of the atmosphere, so that the necessary conditions,

$$\frac{v^2}{2g} + p = h,$$

may be fulfilled when $\frac{v^2}{2g}$ is less than h. Or, in other words, so that the velocity of discharge, v, can be reduced and the discharge area, $2\pi r b \sin. \beta$, be increased accordingly.

For accomplishing this purpose, Fig. 22 shows a scheme which has some additional points of advantage. In this, the air in the chamber n, is not taken directly from the atmosphere, as in the previous propositions, Fig. 11. It is first taken into the intake or suction pipe, Q, through a cock c_3 (or, if the water is naturally gaseous, c_3 may be closed or omitted). The air then passes through the pump as entangled bubbles, and is drawn out of the discharge pipe wherever most convenient, and permitted to enter the chamber, n, through the pipe, S, the rate of passage being controlled by a cock, c_2.

That the above described action can be obtained will be apparent from the following:

The pressure of the air in the discharge pipe will be that due to the

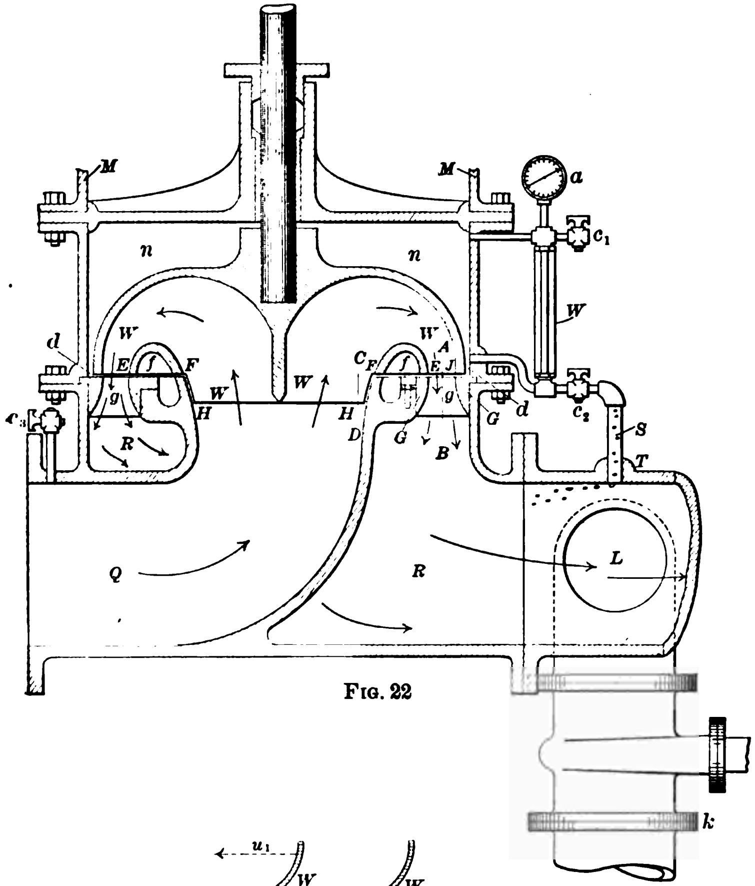
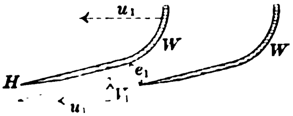
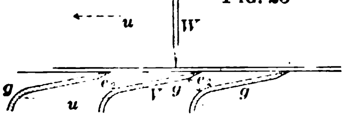


FIG. 22



DEVELOPMENT OF INTAKE VANES, ON *C-D*.

FIG. 23



DEVELOPMENT OF FIXED VANES, *g*, ON *A-B*.

FIG. 24

remaining lift, *h*, while that in the chamber, *n*, must be the same as the pressure in the water as it passes the open joint, *d*. Now, by well-known laws of hydraulics, the pressure at the joint, *d*, where the velocity is high ($v^2 = V^2 + u^2 + 2\ u\ V \cos.\ \beta$), cannot be as great as that in the discharge pipe where the velocity is low (the slight difference of elevation being neglected). Hence there will be a tendency for the fluid to flow through the pipe, *S*, and the cock, c_2, into *n*. The pipe, *S*, of course, should tap the discharge pipe at a point where the air tends to collect. A very small stream of air entering c_3 will suffice, for all that is necessary is to replace the leakage of air through the stuffing-box. The circulation can be controlled by adjusting the cocks, c_3 and c_2. Any surplus of air will pass off through the discharge pipe. The water gauge, *W*, will show whether or not the chamber, *n*, is free of water. The pressure gauge, *a*, is not essential, but should always be attached, as it gives valuable information.

The advantage of this scheme, as announced at the outset, is that the width, *b*, or *E J* of Fig. 22, is not restricted; but, where high efficiency is the object, the fixed deflecting vanes, *g g* (Fig. 24), should be inserted to turn the water downward, thus stopping its revolution and checking its velocity accordingly, as soon as it leaves the propeller (more fully explained later). This will prevent what might be serious loss due to fluid friction.

In this design the propeller vanes, *W W*, extend to the center (though this is not essential). By this means, it is believed, the water will be taken up with less shock, and can be brought to a state of steady rotation before discharge, with more certainty and with fewer propelling vanes. With this intention, the designer should see that the vane everywhere parts the approaching water without conflict. To meet this condition the vanes should be vertical at the center and have a gradually increasing forward pitch at the lower edge as the distance from the center increases.

Notice that there is no tendency for the water to flow back through the joint, *E F*, for the water at *F* is already under centrifugal force, and hence there is as much tendency for the water to flow out through *F E* as to flow back.

The design, Fig. 22, is the writer's study, to combine, in the highest degree, compactness, simplicity of castings, and efficiency. Some other designs embodying the chief features are shown in Figs. 30 and 32.

When this style of pump is to be applied in dredging, the deflecting vanes, $g\ g$, should be omitted, the propelling vanes, W, made few and strong, and the receiving chamber, R, be made a "volute," that is, the area of R should increase progressively in the direction of revolution, and the water in it should move in the direction of revolution only. Thus modified, there is no apparent reason why it should not give excellent results as a dredge pump. Note that grit cannot get to the bearings, and that the area of discharge is unrestricted.

Concerning the pressure, p, in the chamber, n, the following may be interesting:

A necessary relation is $\frac{v^2}{2g} + p = h$.

Doubtless, such pumps will usually be made with the outer tips of the propelling vanes perpendicular to the direction of motion ($\beta = 90°$); then $v^2 = V^2 + u^2$. Substituting, we get

$$\frac{V^2}{2g} + \frac{u^2}{2g} + p = h.$$

Now, the object of this design is to make V small, and it should be less than 8 ft. On this assumption, $\frac{V^2}{2g}$ will be less than one. Hence, for the present purpose, it may be neglected. Remember, also, that $\frac{u^2}{g} = H$. (See pages 487 and 488. Substituting this, the relation becomes $p = h - \frac{H}{2}$, approximately.

Theoretically, the equations derived heretofore will apply to this design; but, practically, they are of little value (except the relation, $u^2 = g\,H$), for in this case a convenient value for V (4 to 8 ft. per second) can be assumed, and the parts proportioned consistently.

That the assumed V may be realized, the actual effective lift must be something less than the maximum theoretic lift, H, reduced by whatever friction losses occur beyond the open joint, d. This is a matter that cannot be formulated. Experience alone can give light upon it.

Relation of Vanes to Each Other.—In the preceding discussions it has been pointed out repeatedly that the edges of the vanes should be set so that the passing water will be parted without shock or "eddies," that is, they should be in the plane of relative motion. We have now to consider the best relation of one vane to the next.

It has also been pointed out that the common forms of centrifugal pumps lose, by "drag" at the tips of the propellers, most of the energy due to velocity ("kinetic" energy), and that this is just half of the energy in the water. It is therefore well to give some study to a means of better utilizing this kinetic energy.

The writer proposes that the vanes should be so related as to form flaring nozzles, of the best possible form consistent with other essential conditions of construction, and this should be done both in the starting or intake vanes and in the fixed deflecting vanes at the discharge.

In support of this opinion, attention may be called to the fact, well established by experimental hydraulics, that the efficiency of a properly proportioned discharge nozzle (water flowing toward the contraction) is about 98%, and, while recorded experiments on receiving nozzles (water flowing away from contraction) are not as numerous or varied, it is rational to presume that the action can be reversed, in correctly designed nozzles, without serious loss.*

Figs. 23 and 24 show vanes designed to act as receiving nozzles to go in the pump shown in Fig. 22. Note that the inclination of the vanes on the side from which the water approaches is such that the motion of the water is not affected until it enters the nozzle, *e*. For instance, in Fig. 23, which shows the conditions at the entrance, the water has only a low vertical velocity, which continues undisturbed as it rises under the helicoidal surface of the vane until it is struck and taken in by the orifice, *e*; then, being in the revolving nozzle, that is, between the vanes, it must take the revolving motion quickly. Here, the nozzle moves against nearly still water, while, at the discharge, Fig. 24, the water moves against fixed nozzles. The relative action is similar in the two cases.

---

* On this subject, the writer was somewhat discouraged and puzzled by that portion of the "Lowell Hydraulic Experiments" relating to discharge through a flaring ajutage (nozzle), in which it is pointed out that fifteen-sixteenths of the energy of discharging water was lost in the tube, but there is nothing irrational or discouraging about it when we are reminded that the absolute loss due to friction is independent of pressure. Hence if there had been 100 ft. of head on the nozzle, instead of 1 or 2 ft., with the same velocity, the percentage of loss would have been small. To satisfy himself on this question, the writer prepared the apparatus shown in Fig. 25 and tested the efficiency of the combination under various conditions.

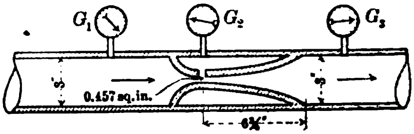


FIG. 25.

The records of two typical cases are as follows:

1.—Pressure head at $G_1 = 167$ ft.; at $G_2 = 0.0$; at $G_3 = 138$. Efficiency = 82.5%

2.— " " " $G_1 = 149$ "; " $G_2 = -28$; " $G_3 = 117$. " = 78.5%

In the first the velocity at the throat was approximately 102, and in the second, 106 ft. per second. Doubtless, for less extreme cases, higher efficiencies can be obtained.

In this design the discharge will vary with the velocity (rate of revolution); then, knowing the peripheral velocity necessary to give the lift, the inclination of the vanes must be computed accordingly.

Example.—Proportion a pump, of the type shown in Fig. 22, with 14-in. intake, to lift 8 cu. ft. of water per second against a head of 48 ft.

First, to find the peripheral velocity, u: If an efficiency of 75% be assumed, the pump must be designed for a speed which would give 64 ft. lift, theoretically. Then, by Equation VII, $H = \frac{u^2}{g}$, $u = 45$ ft. per second (nearly), and this may be taken as the velocity of the center line of the discharge zone. Assume the diameter of this center line to be 24 ins. Then the revolutions per second will be 7.16. The velocity of the outer limits of the intake vanes, W, at H (where the radius = 7 ins.), will be $\frac{7}{12}$ of 45 = 26 (nearly), and, the vertical velocity of approach being 8 ft., the inclination of the vane at this point must be 8 vertical to 26 horizontal (4 to 13). The inclination becomes more nearly vertical as the center is approached, being vertical at the center.

Assuming the width of the discharge zone to be 4 ins., then the area is 1 sq. ft. (nearly), and, therefore, the vertical component of the velocity of discharge (or the velocity, relative to the revolving wheel) will again be 8 ft. (nearly). Hence, the fixed vanes at discharge must be inclined 8 vertical to 45 horizontal (1 to 5½).

Some convenient formulas for proportioning pumps of the class shown in Fig. 22 are as follows:

Let S = slope, or tangent, of the inclination of fixed deflecting vanes, g;
" d = radial width of same = width of discharge zone;
" r = radius of center of discharge zone;
" u = velocity of rotation at radius, r;
" V = velocity of discharge relative to the revolving wheel = vertical component of absolute velocity of discharge;
" a = area of discharge zone = $2 \pi r d$.

Then $V = u S$, and $Q = a V = a u S$.

Similarly, let S_1, r_1, u_1 represent the slope, radius and rotative velocity, respectively, of the intake vanes at the outer limit; and let a_1 represent the area, and V_1 the velocity, in the intake.

Then $V_1 = u_1\ S_1$; $u = \frac{r_1}{r}\ u$; $a = \pi\ r^2{}_1$; $Q = a_1\ V_1 = a_1\ u_1\ S_1$.

Equating the two values of Q, we get

$$r\ a\ S = r_1\ a_1\ S_1.$$

Another equation easily proved is:

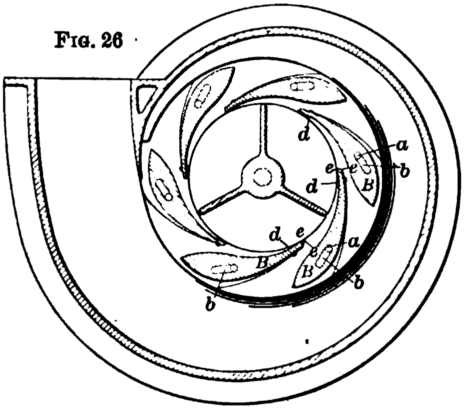
$$r^3{}_1\ S_1 = 2\ r^2\ d\ S.$$

In such a pump, run at varying speeds, the discharge will vary directly with the speed, the lift with the square, and the work with the cube, of the speed. Evidently, then, such a pump cannot be adapted to varying conditions. This has probably been the greatest handicap to a more general use of centrifugal pumps; therefore, it is exceedingly desirable, in connection with other improvements, to make pumps of the best class adjustable.

Figs. 26, 27, 28 and 29 show the writer's design for an adjustable centrifugal pump. The discharge is dependent on the area of the orifices, *e e*, and this is controlled by swinging the vanes, *B*, about the hinges, *d*, thus affecting the opening, *e e*. From the adjusting ring, *A*, Figs. 27 and 28, the pins, *a*, *a*, etc., protrude through short slots, *c c* which are cut through the shell, *D*, on the circumference of a circle concentric with the wheel. These pins, *a*, engage the vanes, *B*, by entering the straight slots, *b*, cut in the vanes. When *A* is revolved, the pins, *a*, follow the slots, *c c*, and *B* must swing in or out accordingly. *A* is revolved through the necessary angle by the mechanism shown at *C*, Figs. 27 and 28, which may be duplicated on the opposite side. Fig. 26 shows the vanes, *B*, in place, with the upper plate removed. Fig. 28 shows the adjusting ring, *A*, lying in place. The inner curve of the vanes, *B*, is designed to maintain unchanged both the radial and revolving motion of the water; but, after it passes *e e*, into the flaring nozzle, the velocity is checked, and the pressure is increased accordingly.

The advantage of the down-and-out flow is in the opportunity it gives to support the weight of the wheel, shaft, etc., on high-pressure air from beneath, that is, in the chamber, *n*, In this case, where air occupies the space, *n*, below the wheel, the pressure is uniform, not being affected by the centrifugal force of the water revolving under the wheel, as assumed on page 496; hence, in this case, the uplift will be $\frac{62.5\ \pi\ r^2\ u^2}{2\,g} = 3\ r^2\ u^2$ (nearly), in pounds, when r is taken in feet. This is double the uplift obtained when water is revolving under the wheel—a point well worth notice in designing either pumps or water-wheels to operate on vertical shafts. Air can be conducted into this chamber by the means described on page 514, or by an inspirator, *i*, as shown in Fig. 27. The water for operating the inspirator can be drawn from any point in the discharge pipe. Note that the pressure in *n* is that at the open joint, *l*, at the tips of the vanes, where the velocity is highest, and, therefore, the pressure in *n* will be less than in *R* (one-half, theoretically).

FIG. 26



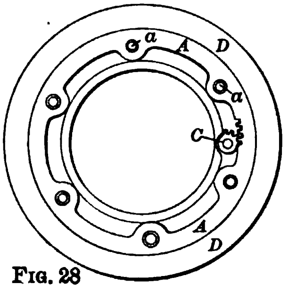
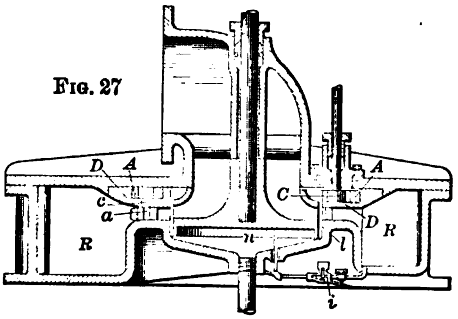


FIG. 28

FIG. 27



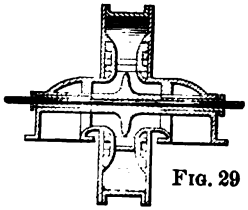


FIG. 29

Fig. 29 shows the outlines of an adjustable, double-intake pump on a horizontal shaft; the adjustment to be made substantially as in the preceding. Such a design has very manifest advantages for a permanent plant to handle large quantities of water from a nearly permanent and easily accessible level.

It is noteworthy that the designs discussed on pages 520 to 521 have every element of a first-class "reaction" water-wheel (turbine), and, operated as such, will probably give good results.

COMPOUNDING.

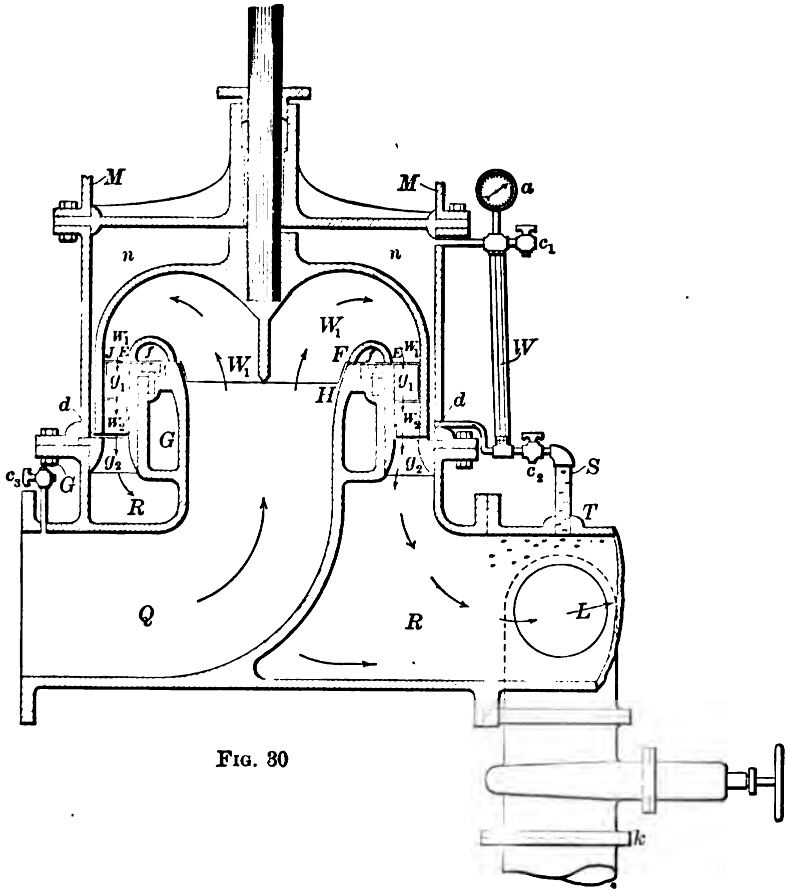
The principle involved in compounding centrifugal pumps is simple enough. It consists in taking the water as delivered from one pump and passing it through another, thus getting the effect of each pump independently. But, when the designer takes up the problem, he finds an infinite variety of possible combinations, from which he must select that one which is most advantageous, everything considered, and he must consider, chiefly, compactness, simplicity of castings and efficiency of operation.

After studying the subject in the light of all that precedes in this paper, the writer offers the design for a compounding pump shown in Figs. 30 and 32.

Having explained all other new features in this design we have now only to explain the features involved in compounding.

The construction and operation, out to the lower edge of the fixed deflecting vanes, g_1 g_1, is identical with that in the single pump, Fig. 22. At this point the water is flowing vertically and has a low velocity (all the motion of revolution having been checked by the vanes, g), and its pressure is that due to whatever head the single pump could produce. The water now comes in the path of a second set of propelling vanes, W_2 W_2, which are attached to the same revolving piece that carried the first set, W_1 W_1, as is shown plainly in Fig. 30. This second set of vanes must be set so that the upper edge will part the water without shock—which is a matter of simple geometry. The water, in gliding between the vanes, W_2, partakes of their velocity, and, hence, at the line of escape, or lower edge of W_2, the water again has a high velocity, as shown by the dotted lines in Fig. 31, but, immediately after its escape from W_2, the water comes against a second set of fixed deflecting vanes, g_2, by which the component, u, of its velocity is again checked and the pressure increased correspondingly, according to the well-known law of hydraulics.

Thus, the pressure can be increased indefinitely by a succession of moving and fixed vanes.


M
M
a
c_1
n
n
W_1
W
W_1
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J
E
f
F
f
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g_1
g_1
H
d
d
W_2
W_2
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g_2
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c_3
G
R
c_2
S
T
Q
R
L
k

Fig. 30

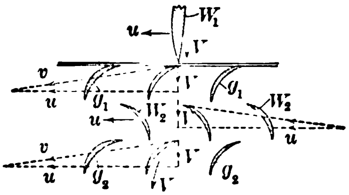

W_1
u
V
v
u
g_1
V
g_1
W_2
u
W_2
u
v
u
g_2
V
g_2

Fig. 31

It can be shown (see page 507) that the effect of the vanes, W_2, will be exactly equal to that of the first set of vanes, W_1, which act more nearly under the laws of purely centrifugal force.

The details of construction can be varied indefinitely, but the simplicity of that shown in Fig. 30 is not likely to be surpassed unless it be by that shown in Fig. 32.

Note that in Fig. 30 the area of the horizontal section of the water channel is constant between the first and last lines of discharge. Hence the vertical component, V, of the velocity must be constant. This simplifies very much the construction and also the problems in proportioning. The flow, of course, could be made radial and yet retain the novel feature here described, but the space occupied by the pump would be increased very much and the construction complicated.

Fig. 32 shows a compound turbine* pump, which will now be readily understood. The water enters from above, through Q. The space, n_2, will be occupied by air below atmospheric pressure (if Q is under suction), the air being admitted through a cock on the pipe, t_1; the air thus admitted doing, also, the duty of that admitted through c_3 of Fig. 30. The space, n_1, will be occupied by air at high pressure admitted through the pipe, S, by the process described in connection with Fig. 22.

This design has one additional and noteworthy advantage, in that the high pressure is under the wheel, and all the reaction of the flowing water is upward. Thus the weight of the wheel and a shaft of length equal to the lift can usually be fully supported, and often more than supported.

As an example of the theoretic porportions of pumps of the style shown in Figs. 22, 30 and 32, the following is offered:

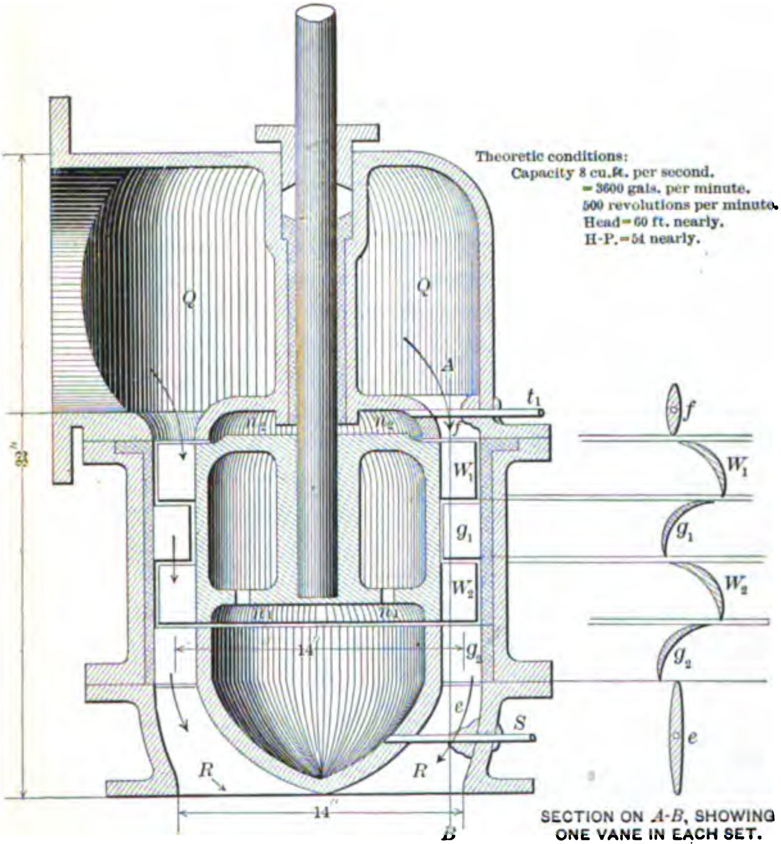
Assume an intake pipe, 8 ins. in diameter, and an intake velocity of 8 ft. per second. This gives 2.8 cu. ft. per second. Assume the outer diameter of the discharge (to J) = 13 ins., and the inner diameter (to E) = 10 ins., or $b = 1\frac{1}{2}$ ins. Then the discharge area = 0.376 sq. ft., and the vertical component of the velocity there = 7.4 ft. per second, and this does not change until the horizontal area changes.

Assume 800 revolutions per minute. Then the velocity, u, of the outer tips of the vanes will be nearly 42 ft. per second, and the theoretic lift, $H = \frac{u^2}{g}$, will be nearly 50 ft. when the outer tips of the propelling vanes are perpendicular to their motion, that is $\beta = 90$ degrees.

---

* This non-committal name is used because the action is neither purely centrifugal nor impulsive.

Under the above conditions, the inner tips of the vanes, where they take up the water at H, should slope 4½ horizontal to 1 vertical, as at b, Fig. 27, and the top edge of the fixed deflectors, g, should slope in the opposite direction about 6 to 1, as at a, Fig. 30.



Theoretic conditions:
Capacity 8 cu. ft. per second.
= 3600 gals. per minute.
500 revolutions per minute.
Head = 60 ft. nearly.
H-P. = 54 nearly.

SECTION ON A-B, SHOWING ONE VANE IN EACH SET.

COMPOUND TURBINE PUMP.

FIG. 32.

The extreme outside diameter (over the flange) of such a pump would be about 21 ins. The figures are drawn to scale and show the proportionate heights.

The lift found for a single-acting pump can be doubled (theoretically) by compounding, as in Figs. 30 and 32, which are drawn to scale and show how little additional weight or work would be necessary to accomplish that result.

FANS.

The demonstrations and formulas heretofore given, relating to both centrifugal and impulse pumps, apply to any fluid of constant density. Notice that weight, or density, appears in none of the formulas for dimensions, velocities or heads. If, then, we enter the study of fans or blowers, assuming that the change of density of the air (or any gas) while passing through the machine is so slight that it may be neglected, we can accept without question any of the formulas offered for either centrifugal or impulse pumps. Indeed, it has already been stated that in impulse pumps there should be no change of pressure in the fluid as it passes through the vanes. Then the formulas for impulse pumps apply to fans, without any qualifications.

It will be shown presently that the simplest, cheapest and probably the most efficient fan will discharge under atmospheric pressure. It will now be shown that in that case, also, the equations will stand, although centrifugal force may cause a compression within the wheel.

In Fig. 1 assume the cylinder, *C B*, filled with a compressible fluid, as air, then the weight of a unit volume will not be constant, but will depend on the distance, x, from the center.

Let W' represent this weight at the distance, x, from the center. Then the centrifugal force, due to a disk of unit area and infinitesimal thickness, $d\,x$, will be

$$d\,f = \frac{W'\,u_x^2}{g\,x}\,d\,x = \frac{W'\,u^2}{g\,r^2}\,x\,d\,x, \text{ since } u_x = \frac{x}{r}\,u.$$

Also,

$\frac{W'}{W} = \frac{f}{p_a}$, where $f =$ the absolute pressure in the fluid at the distance, x, from the center, and W and p_a are the weight and pressure, respectively, of free air.

Substituting and dividing by f we get

$$\frac{d\,f}{f} = \frac{W\,u^2}{g\,r^2\,p_a}\,x\,d\,x.$$

Then

$$\int_{p_a}^{p_1} \frac{d\,f}{f} = \frac{W\,u^2}{g\,r^2\,p_a}\int x\,d\,x.$$

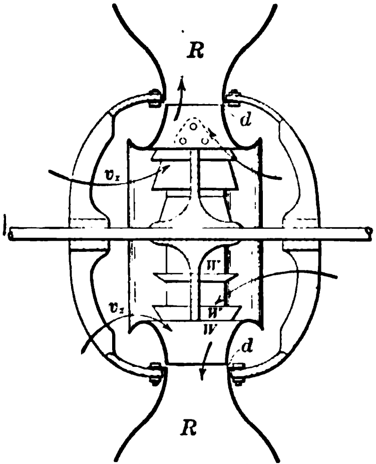
Whence,

$$\log.\ \frac{p_1}{p_a} = \frac{W u^2}{2\ g\ p_a\ r^2}\ (r^2 - r^2_1)$$

Whence p_1 is the pressure at the outer limit, B.

Now, assuming no change of temperature, it is known that whatever energy is pent up in the compressed gas within the wheel must be as kinetic energy (energy of motion), when the gas escapes under atmospheric pressure. The energy in the gas within the wheel is partly in the pressure and partly in the velocity of revolution. Hence we have the equation

$$p_a\ Q_a \log_e.\ \frac{p_1}{p_a} + \frac{W\ Q_a\ u^2}{2\ g} = \frac{W\ Q_a\ v^2}{2\ g};$$



IMPULSE FAN.
FIG. 33.

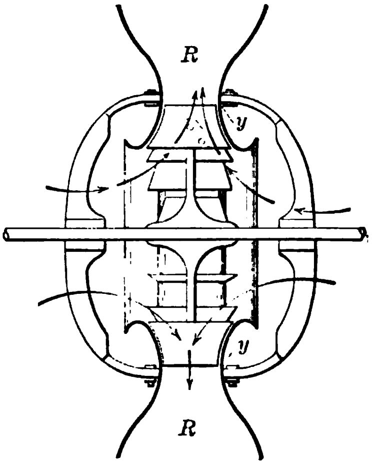


FIG. 34.

where v is the absolute velocity immediately after escaping. Substituting the value of $\log.\ \frac{p_1}{p_a}$, found above, the equation reduces to $v^2 = 2\ u^2 - u^2_1$, which expression will be obtained by the analysis on page 482 when the velocity of approach is omitted.

In the writer's opinion, fans should be designed and proportioned in accordance with the principle of impulse pumps, except that the enclosing casing can be omitted. See Fig. 33. Such constructions have the following advantages:

(*a*)—They are composed of few and simple parts.

(*b*)—The vanes being short, radially, great inlet area can be provided in a fan of comparatively small diameter, and the discharge increased correspondingly.

(*c*)—The condition that the discharge is at atmospheric pressure renders the mathematical analysis of the action simple, and satisfactory formulas for proportioning and speeding a fan can be obtained.

(*d*)—The condition as to pressure (or suction) at the joint, *d*, reveals whether or not the wheel is speeded and proportioned properly.

Furthermore, these impulse fans (if that name be accepted) will for reasons of simplicity and economy, probably be without guide vanes, and, for similar reasons, the moving vanes may be assumed to be radial at the outer end. It is apparent, further, that since the air enters and leaves at atmospheric pressure, the two factors, *k* and *p*, in the equations, disappear or balance each other. Thus simplified, the principle formulas become:

$$v^2 = V^2 + u^2 = 2\,u^2 + v_1^2 \ldots\ldots\ldots\ldots\ldots \quad (XI)$$

$$Q = 2\,\pi\,r_1\,b_1\,v_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (IXa)$$

$$Q = 2\,\pi\,r\,b\,V \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (VIIIa)$$

As the air passes by the joint, *d*, its energy is all kinetic, or $E = \frac{W\,Q\,v^2}{2\,g}$, but after it gets into the discharge conduit its energy will usually be partly due to pressure and partly due to velocity. Thus, suppose there is required an absolute pressure, p_2, and a velocity, v_2, in the conduit; then, by the law of conservation of energy,

$$E = \frac{W_a\,Q_a\,v^2}{2\,g} = p_a\,Q_a\,\log_e \frac{p_2}{p_a} + \frac{W_a\,Q_a\,v_2^2}{2\,g}.$$

Whence,

$$v^2 = \frac{2\,g}{W}\,p_a \log._e R + v_2^2 \ldots\ldots\ldots\ldots\ldots \quad (XVI)$$

Where log. R = hyperbolic log. of $\frac{p^2}{p_a}$, W = weight of air = 0.076 lb. when the temperature is 60° Fahr., and $p_a = 2\,116$ lbs. per square foot. Inserting the numerical values, we get

$$v^2 = 1\,782\,000 \log. R + v_2^2 \ldots\ldots\ldots\ldots\ldots \quad (XVIa)$$

While Equation *XVIa* is theoretically correct, it is the common practice to neglect the effects of compression, and work by equations identical in form with those used in hydraulics, differing only in the weight of the fluid and in the coefficient of friction. This practice is sufficiently accurate for practical purposes, within the ordinary limits of compression produced by fans. Thus, instead of the equation above for E, the equation for energy would be written

$$E = P\,Q_1 + \frac{W\,Q_a\,v^2_2}{2\,g} = \frac{W\,Q_a\,v^2}{2\,g};$$

where P is the pressure above the atmosphere, and Q_1 is the volume at the pressure, P; but, if compression is neglected, Q_1 may be taken $= Q_a$; then Equation *XVIa* reduces to

$$v^2 = \frac{2\,g\,P}{W} + v^2_2 \ldots\ldots\ldots\ldots\ldots\ldots (XVII)$$

or, inserting numerical values, this becomes

$$v^2 = 842\,P + v^2_2 \ldots\ldots\ldots\ldots\ldots\ldots (XVIIa)$$

Results computed from Equations *XVIa* and *XVIIa* will not differ enough to affect the dimensions in designing. Hence, the latter, being much simpler, is preferable for that purpose; but, in computing the efficiency of a fan, Equation *XVI* should be applied, and a value of W inserted, according to the temperature of the passing air.

Example.—Proportion a fan to deliver 400 cu. ft. per second of free air (at a temperature of 60° Fahr.) into a passage where the pressure is 2 ins. of water (10.4 lbs. per square foot), the velocity to be 16 ft. per second ($= v_2$). See Fig. 33.

$$R = \frac{2\,116.8 + 10.4}{2\,116.8} = 1.005;$$

$$\text{Log.}_e\, R = 0.005;$$

and

$$v^2_2 = 256.$$

Then, by Equation *XVIa*,

$$v^2 = 1\,782\,000 \times 0.005 + 256 = 9\,166, \text{ or } v = 96, \text{ nearly.}$$

By Equation *XVIIa*,

$$v^2 = 842 \times 10.4 + 256 = 9\,012, \text{ or } v = 95, \text{ nearly.}$$

Evidently, either result will be sufficiently accurate for designing.

Now, if an entrance velocity, v_2, of about 60 ft. per second is allowed, the area of the entrance $= \frac{400}{60} = 6.66$ sq. ft., or 3.33 sq. ft. on each side. The area of a circle of 1 ft. radius is 3.14 sq. ft. Hence we may take $r_1 = 1$ ft., making $v_2 = 63$.

Assuming the velocity at the entrance to the vanes, v_1, to be the same as v_2, we have,

$$Q = 400 = 2\,\pi\,r_1\,b_1\,v_1,$$

whence

$$b_1 = 1 \text{ ft., very nearly.}$$

Now, if there are twelve vanes, they will be about 6 ins. apart at the inner tip. Then a radial length of 6 ins. for the vane seems to be sufficient. This will make the fan wheel 3 ft. in diameter.

By Equation *XI*,

$$u^2 = \frac{v^2 - v^2_1}{2} = \frac{1}{2}(9\,012 - 3\,960) = 2\,512, \text{ and } u = 50, \text{ nearly.}$$

Also, by Equation *III*,

$$V^2 = v^2 - u^2 = 9\,012 - 5\,043 = 3\,969, \text{ and } V = 63.$$

Then, by Equation *VIIIa*,

$$400 = 6.28 \times 1.5 \times 63 \times b,$$

Whence

$$b = 0.66 \text{ ft.} = 8 \text{ ins., nearly.}$$

The vanes should curve forward at the inner end to make an angle with the tangent, of which the tangent, $\frac{v_1}{u_1} = 1.31$, or the angle $= 52° 45'$.

The theoretic horse-power of such a fan would be

$$\frac{W\,Q_a\,v^2}{2\,g \times 550} = 8, \text{ nearly.}$$

Fig. 33 is drawn to scale showing the dimensions as just computed. The vanes and the hollow wheel in which they are inserted can best be made of sheet metal polished inside and outside.

The curved approach to the inlet should not be omitted. Judging by similar conditions in hydraulics, the discharge will be about 50% greater with a curved inlet than without. Hence, evidently, this is one of the most important details.

Adjustment.—The joint, *d*, is open to the atmosphere. When the wheel is designed and speeded according to principles already discussed, the energy passing the joint, *d*, is all kinetic, so that there is no tendency to leakage inward or outward. However, in most cases in practice, the resistance to be overcome in forcing air through the passage (pipe, mine, tunnel, building, furnace, or the like) cannot be computed accurately, and may vary from time to time. Hence, in order to meet these conditions satisfactorily, it is desirable that the fan should be adjustable. In order to understand this phase of the subject, the following discussion is necessary:

If all effects of compression are neglected, which may be done under the ordinary conditions of practice, the resistance to be overcome when forcing air through a passage, in which the conditions are constant, will vary with the square of the velocity (proved by experiment), and, of course, the velocity varies directly with the quantity of air passed. Hence the resistance varies with the square of the quantity. Also, from Equation *VIII*, it is seen that Q^2 varies with V^2, all other factors being constant; and, by Equation *VI*, V^2 varies with u^2. Hence, from the foregoing considerations, it may be said that the resistance varies with u^2; and, from Equation *XI*, the pressure head produced by the wheel,

$$H = \frac{v^2}{2\,g} = \frac{2\,u^2 + v_1^2}{2\,g},$$

showing that it is sufficiently accurate for the present purpose to say that H, or the propelling force, varies also with u^2, v_1 being comparatively small.

Thus it is found that a fan cannot be adjusted to a variable resistance by varying the speed only. The folly of attempting to do so will be still more apparent when it is considered that the necessary power to run the fan varies with the cube of the speed, if it has a free discharge

The problem of adjustment, then, is reduced to this: Either change the resistance by changing the quantity of air delivered without changing the speed, or change the speed (and thereby the propelling force) without changing the quantity; or possibly, both may be changed at once. In any case, it would be necessary to make the area of the air passage adjustable. Theoretically, the adjustment ought to be made in the area of the discharge passage from the wheel; that is, *b*, in the equations, should be adjustable; but, practically, it is very doubtful if the advantage would outweigh the disadvantage of mechanical complications necessary to provide for such adjustment. The discharge could be adjusted as in the adjustable pump.

The area of the inlet could easily be throttled to any extent, and some provision to do so may be found advantageous, though, theoretically, it is not the proper place to apply the adjustment.

Attention should be called to the fact that the conditions at the joint, *d*, will indicate to the attendant whether the speed and volume of discharge are properly related to the resistance, that is, if air is escaping at *d*, the resistance is too great, or the wheel is discharging more air than it can force through the passages; while, if air is being drawn in at *d*, the resistance is less than the wheel could overcome, or the wheel could send more air through the passages.

The writer suggests that, until experience throws light on this part of the study, the area of the discharge slot be made a little less than computed. Then, by speeding up, the required quantity can be obtained, and there will be some excess of propelling head. Without this suggestion it is probable that the designer would suppose that in order to be on the safe side both area and speed should have some excess.

Fig. 34 represents a fan in which the vanes are open on the side, and turn within a fixed casing. Otherwise, the proportions should be worked out as for Fig. 33. This construction is not as simple or as economical as that shown in Fig 33, though it represents present practice more nearly. Nor would it indicate whether the proportions and speed were properly adapted to the resistance. However, an orifice through the casing, as at y, on the line of least width, would give the needed indications, provided the proportions are in accord with the method described on pages 528 to 530. The idea is apt to prevail that by closing up the sides of the fan, as in Fig. 34, the air is kept in the passage and forced to move on into the conduit; but this would be an error, for if the propelling head, $\frac{v^2}{2g}$, and the possible volume are not properly related to the resistance, any excess of volume will not enter the fan. Attention to this fact will explain the paradox that, within assignable limits, the more open the passage in a mine the more power is required to run the fans. Close the passage, and no air passes. Then, though the fan continues to run, it discharges no air, and the power required is only enough to overcome the friction within the fan. This is one extreme. The other is, when there is no resistance outside the fan.

TESTING CENTRIFUGAL PUMPS.

Unfortunately, the published data taken in testing centrifugal pumps are incomplete in every case that the writer has examined. The only object in making the tests seems to have been to see if the pumps met the conditions of the contract. That, of course, is the most important matter, as far as a single pump is concerned, but what are most needed are comparative results as affected by variations in proportions, angles, speed and head. It is only from such data that we can interpret results intelligently and detect the combinations that give the best results.

The data which should be recorded in a test are:

First.—All dimensions and details of the water passages, including:

(*a*)—Suction pipe; length, diameter, valves, etc.;

(*b*)—Curves of entrance to the wheel, and details of the joint between the wheel and the casing when the runners are inclosed;

(*c*)—Angles (Δ and β) of the intake and discharge ends, respectively, of the propellers, with a tangent to the circle in which they move;

(*d*)—Details of the open joint between the runner and the casing at the discharge, when inclosed runners are used;

(*e*)—Details of the curve, if any, through which the water passes from the tips of the propellers into the "volute";

(*f*)—Dimensions of the "volute";

(*g*)—Conditions of the various surfaces as to polish.

All the above can be shown by two sections; one through the center in the plane of revolution, the other through the center at right angles to the plane of revolution. Dimensions should be shown in figures.

Second.—The pressures at three points, *a*, *b* and *c*, should be recorded, as follows:

(*a*)—In the suction, as near as possible to the wheel, but on a straight pipe or channel;

(*b*)—At the outer tip of the propellers, by tapping through the casing at right angles to the plane of revolution;

(*c*)—In the first straight section of the discharge pipe;

(*d*)—Relative elevations of the gauges at *a*, *b* and *c*.

Care must be taken to place the gauges where centrifugal force will not affect the results. When the gauges are set thus it will not be necessary to take the elevations of the water surface in the sump and discharge.

Third.—(*a*)—Speed, or revolutions per minute;

(*b*)—Water delivered;

(*c*)—Power consumed when discharging;

(*d*)—Power consumed with pump full of water, but without discharge;

(*e*)—Power consumed when pump is running empty.

Fourth.—The following points should not be overlooked in preparing for and in conducting a test:

(*a*)—The pump cannot start a discharge under a head that it can maintain after starting. Hence, a valve discharging under low head should be provided.

(*b*)—It will seldom be found practicable to deliver the water to a stand-pipe with the desired head, especially when it is desired to vary the head, as will usually be the case. Then the only recourse is to throttle the discharge beyond the pressure gauge in the discharge pipe. In doing this, remember that with the discharge cut off entirely the maximum pressure head will be $\frac{u^2}{2g}$, including suction, and, as the valve is gradually opened the pressure head will rise, theoretically, to a maximum of $\frac{u^2 + u\,V \cos.\beta}{g}$, including suction head, after which, if the valve be opened further, the head will become less. Thus a skilful manipulation of the throttle valve while watching the pressure gauge should enable the operator to find the maximum lift for any speed readily. Theoretically, the condition that gives the greatest lift should also give the greatest efficiency. Practically, the greatest efficiency will probably be found when the valve is opened a little wider than when giving the greatest lift.

(*c*)—The total lift to be credited to the pump is the head shown on the suction gauge plus that on the discharge gauge plus their difference of elevation. The elevation of the gauges should be assumed at the surface of the water standing in the small pipe leading to the gauge, and some provision to determine this should be made.

APPENDIX.

While pursuing these studies, the following scheme for a hydraulic air-compressor occurred to the writer. It is a natural result of the ideas presented on pages 494 to 496.

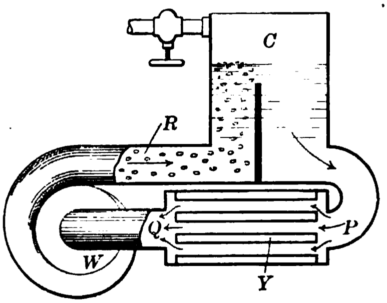


Fig. 35.

Let *W*, Fig. 35, represent a centrifugal pump working in a closed circuit, *P Q R*, as shown; then, evidently, neglecting slight differences of elevation, the pressure in *Q* is equal to that in *R* (see also Figs. 11 and 18). How, then, can we account for the work done by the pump?

The answer depends on circumstances. For our present purpose we will assume an air space, *C*, somewhere in the circuit, and that free air has access to the joint, *d*, through the spaces, *n*, Figs. 11 and 18. Under these circumstances the rush of water through the flaring nozzle, *m*, into a relatively unresisting field (since the pressure in *R* equals that in *Q*) will cause a suction at the joint, *d*, and, assuming proper provisions for the admission of air, the entering air will be compressed to the pressure in *R* as soon as the velocity is checked.

The air thus compressed can be separated in a chamber, *C*, and thence conducted away. Theoretically (as the word is usually applied), we should find the energy in the compressed air equal to the work done by the pump, there being no other channel through which the energy can disappear except by friction in its various forms.

The water would absorb the heat of compression, and therefore isothermal conditions would be very nearly realized, but the heat thus absorbed would have to be taken out by exterior cooling, as suggested at *Y*, Fig. 35.

Another attractive feature in the scheme is that, theoretically, with nearly constant motive power and speed, the degree of compression can be varied indefinitely and the quantity of air entering will be self-regulating.

An easy computation will show that a compressor of great power and volume can be embodied in a small machine.

Disregarding cost, if mercury be used instead of water, the calculations show remarkable results.

If the air-chamber be abolished, or filled with water, and water, instead of air, be drawn in at *d*, we have a hydraulic jack of unlimited power.

The practical difficulties in carrying out such a scheme will probably be serious, and possibly insurmountable. To test it sufficiently to say whether or not it can be made a success would require extensive and expensive experiments. The main questions are: Can enough air be taken into the current to absorb the energy; and what is the best mechanical means for providing for its admission?

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

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PAPERS AND DISCUSSIONS.

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AN INVESTIGATION OF THE PROPERTIES OF BRICK, UNDER DIFFERENT PHYSICAL CONDITIONS.

Discussion.*

By E. J. McCaustland, Assoc. M. Am. Soc. C. E.

Mr. McCaustland.

E. J. McCaustland, Assoc. M. Am. Soc. C. E. (by letter).—In conducting these tests, which show a great amount of painstaking labor on the part of Mr. Turrill, an excellent opportunity was offered to determine the rate, as well as the total amount, of absorption. With bricks heated for the time, and to the degree indicated in these experiments, and with the time allowed for the complete test, valuable information might have been obtained by weighing the bricks at frequent intervals during the period of immersion.

There is little doubt that the rate of absorption is much greater during the first few hours of immersion than at any later time, although there will be increasing absorption for a long period.

In ordinary commercial work it is not usually convenient to extend the absorption tests over more than 48 hours, and sometimes not more than 24 hours. The latter time is rather short; but the writer believes that 48 hours gives sufficient time to indicate clearly the character of the brick and give results definite enough for all purposes of comparison. It is probable, in any case of building brick and most cases of paving brick, that at least 75% of the total water of absorption would be taken up during the first 48 hours of immersion,

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* This discussion (of the paper by Sherman M. Turrill, Assoc. Am. Soc. C. E., printed in *Proceedings* for March, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.

Communications on this subject received prior to June 26th, 1903, will be published subsequently.

Mr. McCaustland.

and it is believed that this initial absorption affords fully as satisfactory an index of the character of the brick as would be obtained from a more extended test. Certainly, it is absorption in the first stages that is important to consider in ordinary brickwork where it is exposed to moisture. Brickwork under water is usually constructed of a material which will absorb only a very small percentage of its own weight.

The writer believes that tension tests of brick should receive more attention than has been given to them heretofore. In crushing tests of a large number of brick piers or columns, he has found that failure occurred invariably by splitting longitudinally, the individual bricks failing by tension, with little or no indication of crushing.

The author's conclusions, based upon the results of his tensile tests, concerning the comparative strength of natural, filled-with-water, and reheated bricks seem to be scarcely justified. It is true that on the twelve tests the average strength of the reheated bricks is highest; but it is to be noted that two of these specimens (Nos. 96 and 231) give abnormally high results. With these omitted, or scaled down to the next highest figure (No. 491), the average will be practically the same as for the natural brick. Comparing the "filled-with-water" and the "natural," it is to be noted that six of the latter give a higher value than the corresponding "filled-with-water," and on the whole set of twelve bricks the averages for the three conditions differ only 8 lbs.

It would seem to the writer more nearly correct to conclude that these tests do not establish any difference whatever in the tensile strength of these three classes of brick. The stresses due to bending, although not to be classed as tensile stresses, have some significance in this connection, and their averages indicate an excess of strength in favor of the natural brick. However, notwithstanding the extent of these experiments and the care with which they were conducted, they are not sufficiently numerous to warrant general conclusions.

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PAPERS AND DISCUSSIONS.

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THE FILTRATION WORKS OF THE EAST JERSEY WATER COMPANY, AT LITTLE FALLS, NEW JERSEY.

Discussion.*

By Messrs. Allen Hazen, J. P. A. Maignen, C. L. Harrison, J. Waldo Smith, R. S. Weston, G. C. Whipple, W. B. Fuller, L. L. Tribus, Langdon Pearse and John H. Gregory.

Allen Hazen, M. Am. Soc. C. E.—This paper is of unusual interest, as it represents a careful and scientific development of a method of filtration which has been used extensively in this country in a less perfected and developed form. This method is that commonly known as mechanical filtration, in distinction from the older type known as sand filtration, which has been used widely by European cities for many years, and more recently to a considerable extent in this country. Mr. Hazen.

The water at Little Falls is free from excessive sediment, and is of a type for which sand filters would usually be considered preferable. For waters of the turbid type, particularly where the amount of sewage-polluting matter is not great, mechanical filters give better clarification than sand filters. Mechanical filters, because of their high rate of filtration, occupy less space and can be installed on sites which are not adequate for the construction of sand filters; and, apparently, it was for this reason that mechanical filters were selected in this case, although the removal of color, which is more complete in connection

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* This discussion (of the paper by George W. Fuller, Assoc. M. Am. Soc. C. E., printed in *Proceedings* for February, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.

Communications on this subject received prior to June 26th, 1903, will be published subsequently.

Mr. Hazen. with the chemical treatment than is possible by sand filters unaided, was no doubt an important, although secondary, object reached by the selection.

As far as the clarification is concerned, there can be no question as to the treatment. The results secured, as shown by the records given by the author, are almost ideal. The point of greatest interest in connection with its operation is, whether it will remove the disease-producing properties with the same certainty that well constructed and operated sand filters do.

Most of our knowledge as to the improvement of the health of communities by filtering their water supplies relates to the changes effected by sand filters. Corresponding data for mechanical filters are as yet limited and unsatisfactory. The figures for bacterial efficiency given by the author promise much in this respect. It should be noted, however, that the raw water is much less polluted by sewage than the corresponding water in many places where sand filters have been used, as for example, at Poughkeepsie, Lawrence and Albany; and, as the author states, the death rates of the population supplied in the past with the water in its raw state have not been excessive. The test is thus a less searching one than would have been the case under other conditions, and, at the same time, the conditions left less room for doubt as to the outcome, from a sanitary standpoint, than would have been the case had the raw water been polluted by sewage to a much greater extent.

In a sand filter operating at a low rate of filtration, the removal of the disease-producing properties, which are, in general, the bacteria, seems to depend upon the attraction of the bacteria for the sand, and for the matters which accumulate upon the sand grains in the course of filtration; and that action, as we know, is such that the removal of the bacteria is most complete. In a mechanical filter the rate of filtration is increased, in a general way, forty times. The result of this increase in rate is that the actions which make the sand filter efficient are no longer adequate to remove the bacteria, and the action of the filter becomes dependent upon the addition of coagulant to the water before filtration, and the formation of a flocculent precipitate in it which entangles the bacteria and allows them to be removed at the high rate. The efficiency of the filter, in this respect, depends absolutely upon the faithful and continuous application of coagulant. The problem reduces itself to devising mechanical means for securing at all times the application of the coagulant to the raw water in the right amount. If this can be accomplished thoroughly there can be no doubt as to the efficiency of the purification secured.

There are a great many mechanical filter plants in the United States. Unfortunately, most of them have failed in this respect at times. In some of them the failures have been so frequent and extended as to

Mr. Hazen.

be habitual. Others have failed less frequently, but they have failed more frequently because the coagulant was not applied faithfully and continuously than from any other cause. In this plant a decided step has been taken in securing devices to insure the continuous application of the coagulant, as far as devices can be secured; for, after all, the human element is often the weakest link in the chain, and that cannot be eliminated altogether.

The probability of satisfactory operation is increased greatly by the laboratory which has been established in connection with the plant, where the operation is watched with care and in detail, and the results are recorded fully and impartially. This is a most important step in securing uniformly excellent results, and it is to be hoped that it will be followed in all important plants. The importance of such supervision is shown in the tables of results and by the fact, as noted by the author, that the lowest efficiencies obtained have followed the failure to secure perfect operation of the coagulating apparatus. Without the laboratory, these slight lapses would have passed unnoticed, and the improvements in the apparatus to correct them would not have been made.

A large part of our accurate knowledge of mechanical filtration has been derived from certain experiments made by the author at Louisville, Ky., and by the speaker at Pittsburg, Pa. In each case filters of what are known as the Warren and Jewell types, as well as certain other appliances, were installed. A comparison of some of the features of these earlier experimental filters with the Little Falls filters may be of interest. Some of the figures, necessarily, are only approximate.

TABLE No. 17.

	Little Falls filters.	Louisville Experimental Filters.		Pittsburg Experimental Filters.	
		Jewell.	Warren.	Jewell.	Warren.
Capacity of coagulating basin, in hours' supply, when rate of filtration is 125 000 000 galls. per acre daily	1.28	0.48	1.15	0.49	0.89
Depth of sand, inches	30	34	27	57	27
Effective size of sand, millimeters	0.40	0.43	0.51	0.46	0.70
Uniformity coefficient of sand	1.50	1.65	1.47	1.40	1.30
Diameter of holes in strainer system, millimeters	1.60	0.71	1.09	0.63	0.61
Percentage which holes in strainer system are of filter area	0.26	1.44	6.00	1.20	8.30

Mr. Hazen. The Pittsburg and Louisville experimental filters may be regarded, in a certain sense, as prototypes of the Little Falls filters, and it is interesting to note the changes from the earlier designs.

The coagulating-basin capacity at Little Falls is increased. Undoubtedly this change is most advantageous, and it may be questioned whether still further increase would not be desirable. The best size for the coagulating basin depends almost entirely upon the character of the raw water, and a size most advantageous for one water might be quite inadequate for another.

In the depth of sand there is but little change, although the very deep layer used in the Jewell filter at Pittsburg has not been repeated. The sand is slightly finer than in the earlier filters, but the change is not important, and the uniformity coefficient, which was insisted on rigidly at Little Falls, is about the same as in the earlier filters.

The size of the holes in the strainer system is much greater, but the total area of the holes is reduced. The large size of opening is only possible in connection with the considerable gravel layers at the bottom, and these layers are no doubt necessary with the smaller total area of the openings.

The ample area of the exit holes in the Warren filters has much to commend it. If the action of filtration was all that had to be considered, the size would hardly have been reduced below this figure. The disadvantage of the large strainers is in the washing. With them there is not sufficient control of the points at which the wash-water rises through the sand. The only way that this has been controlled adequately has been to restrict the sizes of the openings in the strainer system, until so much head is consumed in forcing the water through that a good distribution of the water is secured over the whole of the area. In the Jewell filters, this was secured by taking the water through necks immediately below the strainer outlets, these necks having an area of only approximately 0.07% of the filter area. This arrangement secured a very good distribution of wash-water, but was open to the objection of having an abnormally high friction for both the entering and leaving water.

In the Little Falls design, the holes in the strainers themselves represent the greatest amount of contraction, and the area of these holes, while much less than the area of the holes in the Jewell strainer systems, is three or four times as great as the area of the necks back of those holes.

The strainer system serves two widely different uses. In normal operation, it collects and removes the filtered water; in washing, it distributes the wash-water, and the distribution to all parts of the filter bottom must be substantially equal. The requirements of the two services are quite different, and the strainer system is a compromise

Mr. Hazen.

between the requirements of each. The speaker has often questioned in his mind whether the best possible results could be secured without using separate systems for the two services.

The most important point of divergence from the earlier designs is the substitution of air for agitating the sand during washing for the rakes driven by power, which served this purpose in all the earlier filters. Air agitation has been used on many smaller filters, but not before where the results were actually recorded and made available for study by those interested in the art of water purification. The air agitation has the advantage, in its ready applicability to rectangular masonry filters, and in avoiding the necessity of having power and shafting over the filters. It seems to work well at Little Falls, and the present indications are that it may largely supersede other forms of agitation.

The excellent manner in which concrete has been used in all parts of the design is most creditable to the constructing engineers.

Mr. Maignen.

J. P. A. **Maignen**, Assoc. Am. Soc. C. E.—The expression "ripening" of filters has been used by Mr. Fuller, and the speaker would like to ask him and Mr. Hazen what, in their opinion, is meant by it. Is it that the surface of the grains of sand becomes more or less covered by water bacteria, and do these bacteria help the act of purification in any other way than by blocking the interstices between the grains of sand; or, on the contrary, are we to understand that a sand filter becomes "ripe" or capable of giving a good bacterial effluent when the sand has been deprived of the air germs it contained before any water had been passed through the filter? In other words, does the "ripening" imply the addition of water bacteria to the sand, or the elimination of air germs from the surface of the sand grains by a more or less prolonged flow of water? Some light on this subject might not be without interest.

This brings us back to a statement made by the speaker in discussing the topic "The Decolorization of Water,* when he cited some experiments he had made during several months with filters containing granular materials—sand and charcoal. In both cases practically sterile water was applied (from 8 to 20 bacteria per cubic centimeter). The effluent, during the first two or three days, had from 100 to 300 bacteria per cubic centimeter, and, day after day, although the applied water was always the same (not averaging more than 15 bacteria per cubic centimeter), the filtrate went on showing an ever increasing number of bacteria, until the fifteenth day, when it had reached upwards of 5 000. Then the number of bacteria in the effluent began to fall off, until, at the end of the month, the filtered water did not contain more than the applied water (about 15 bacteria). Therefore, it took one month to "ripen" these filters. They were kept in opera-

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* *Transactions*, Am. Soc. C. E., Vol. XLVI, p. 168.

Mr. Maignen. tion for more than three months afterward, and during all this second period—that is, after the filters had been "ripened"—the applied water never contained less than 2 000 bacteria, sometimes it contained 5 000 or more, and the filtered water never contained more than 20.

How can the large number of bacteria found in the filtered water during the first fortnight be accounted for? It cannot be, as has sometimes been said, that the granular materials are favorable to the development of water organisms introduced with the applied water, because, in this case, the applied water was practically sterile. If the theory of the multiplication of the bacteria in the filter were attributed to the accumulation of mud, how was it that, all of a sudden, and forever after a certain time (nothing being done to sterilize the materials), the number of bacteria in the filtered water went on diminishing daily until it became as low as in the applied water and continued practically sterile for months, although the applied water after the first month contained a very large number of bacteria?

A plausible explanation is to be found in the fact that when granular materials—sand or charcoal—are new the grains are surrounded with dust partly made up of dry germs. These dry germs may be compared to dry seeds, which, as pointed out by Tyndall, when in contact with water, are softened and incubated, as it were, and they become full-grown bacteria. In this state of life they either go out with the filtered water, or die in the sand without progeny.

The speaker, therefore, suggests that the true explanation of the "ripening" of filters is to be found in the gradual elimination of the original or "constitutional" germs existing in materials which have been exposed to the dust of the air previous to being used in filters.

Some of the speaker's experiments would appear to strengthen this view. One of the sand filters which had been "ripened," as already explained, and was giving perfectly pure water during more than one month, was placed out of service, the old sand was carefully taken out and a thin layer of small pebbles, which had not been washed or used before, was placed at the bottom of the filter, and the old "ripe" sand put back again over the pebbles. During the following days the filtered water became very rich in bacteria, and it was more than a fortnight before the filtrate was as free from bacteria as the applied water.

The ripening of filters, therefore, would seem to consist in freeing the sand from air germs and not in charging it with water bacteria. This is but an idea, for which the speaker has given his reasons, and it is submitted for consideration.

Mr. Harrison. C. L. Harrison, M. Am. Soc. C. E.—This paper presents the modern design and construction of the mechanical filter, and is a valuable addition to the literature on the subject of water purification. The construction is substantial and cleanly, and the design is in accordance with the best recent knowledge of this subject.

Mr. Harrison.

There is one marked difference between the design of this plant and of those which were constructed a few years ago. In the older plants the coagulant was introduced directly into the filtering tanks, while in this one it is mixed with the raw water, which is then allowed to pass through a subsiding basin, from which it is taken to the filtering tanks. This is an important feature of the design, as Table No. 4 shows, for the months of October, November and December, 1902, and January, 1903, that 83, 68, 67 and 58%, respectively, of the bacteria in the raw water were removed before the water left the subsiding basin; and, in addition to this, the sludge is deposited in this basin, instead of in the filtering tanks, where it would clog the sand and necessitate more frequent washings. Some experiments made by the speaker a few years ago show clearly the great value of the subsiding basin, and indicate that one large enough to require more than one hour for the water to pass through it would be desirable. The effect of the basin would be increased very much by taking the water from it at points near the surface. The plans do not seem to indicate how this is done, and perhaps the author will give some further information on the subject. By using a subsiding basin of proper size, the action of the coagulant can be entirely completed before the water reaches the filtering tanks, and the sludge be deposited in the basin, thus increasing the efficiency of the plant in removing the bacteria and reducing to a minimum the quantity of wash-water required.

Mr. Smith.

J. Waldo Smith, M. Am. Soc. C. E.—Since the end of the six months' experimental period mentioned in the paper, there has been one month of normal operation of this filter plant. During that month—March, 1903—the quantity of coagulant was about 15% in excess of the expected average.

The average quantity of wash-water has been about normal; and the plant has been operated at about one-third of its normal capacity.

The cost per million gallons of filtered water delivered into the pipes (wash-water deducted) has been as follows:

Labor	$1.22
Coagulant	1.60
Heat	0.25
Power	0.12
Total	$3.19

If the quantity of water filtered was twice as great as at present, the labor item in the above cost would not be increased. The cost of coagulant would be in proportion to the quantity of water filtered, and the heat and power items would be increased only slightly. In fact, the heat item for March is greater than the average per month throughout the year.

Under these conditions, which will probably obtain within a year, the cost per million gallons would be about $2.50, instead of $3.19, as stated above.

Mr. Weston. R. S. **Weston**, Assoc. M. Am. Soc. C. E.—This excellent paper presents few points which can be criticized unfavorably.

Passing by the discussion of the construction of this intricate monolith, and considering the operation of the plant, one is impressed by the care taken in the design to have everything convenient for the operator. Those who have had to do with the operation of rapid filters have been impressed by the great loss of time and consequent cost incurred for the opening and closing of valves during the washing of the sand layer; but when one goes to Little Falls and sees how easily the filters are operated, how little labor is performed to obtain the required results, he is filled with admiration for the work.

The speaker has made several visits to Little Falls, both during the construction and during the operation of the filter plant, and he doubts if any municipal structure, built during the last few years, has had in it so few things which have had to be changed after the completion of construction, notwithstanding that the Little Falls construction represents many new departures.

The chief of these departures—the use of air as an agitator, during the washing process—permits the rectangular construction of the filter tanks, thereby enabling one to increase the size of the units (tanks) and to abandon the short-lived mechanical agitator and the space-consuming, round filter tank.

The speaker happened to be in Little Falls before the gravel was put into the filters, and while the air and water distribution systems were being tested. The efficiency of these devices was excellent. The water appeared at every strainer at about the same time, and the spray from the strainers appeared to cover the whole bottom of the filter, when viewed from above. The air, also, was well distributed.

The gain in efficiency at Little Falls due to the use of air agitation is well shown in the tables. Whether this agitation by air or by means other than water currents is necessary in all filter plants—that is, enough to justify its cost—is a question. The water at Little Falls might be called fibrous. It contains much vegetable and amorphous matter, which makes a felt on the sand layer during filtration, and which must be removed continuously with each washing, in order to maintain the sand layer at its highest efficiency. The use of air agitation breaks up this felt and the concretions of aluminum hydrate, amorphous matter and sand, and reduces all the matter to particles of such a hydraulic value that they can be removed more readily, subsequently, with the wash-water. Whether agitation would be necessary with a water containing only crystalline, silty and finely divided suspended matter (which does not seem to form a mat or felt on the surface of the filter), and where the expense of the agitator is a consideration, must be left to the future and to the larger plants for its solution.

Certainly, the experience which will undoubtedly be gained from the operation of this plant will establish the system of rapid filtration upon a firm, rational and scientific basis, and it must be felt by all that, at least after the proposed plants at Louisville, Cincinnati and New Orleans are completed, it will be possible for engineers to design rapid filters with little or no chance of failure, provided all the local conditions are studied carefully. Mr. Weston.

Regarding the preparation of sand for a rapid filter, the speaker agrees with Mr. Fuller that it is necessary to have a uniform sand, of medium size, practically free from particles finer than 0.25 mm. in diameter. To obtain sand of this character is a hard task. Of late the speaker has been attempting to devise an apparatus for the removal of the fine particles, the "dust," from a lot of sand. This means that all particles which would pass through wire-cloth with 80 meshes to the linear inch must be removed. Given, dry sand, it is a simple problem to separate particles which would pass through a screen with 60 meshes to the inch, but a much more difficult one if finer screens are tried.

Thinking that, perhaps, the best method was to dry the sand and pass it through a screen, the speaker designed a hexagonal rotary screen, 4 ft. in diameter and 9 ft. long. The frame of this device carried two concentric, hexagonal, wire-cloth screens, the inner of No. 20 and the outer screen of No. 80 mesh. The screen made about thirty revolutions per minute. It was cleaned, from the outside, by a jet of compressed air.

The sand was heated to a temperature of from 300 to 400° Fahr., and was thoroughly dry. It was then fed into one end of the screen at the rate of about 22 cu. ft. per hour. The results were unsatisfactory. The fine screen clogged quickly—so quickly, in fact, that it became useless after a few days. For the first three or four days, with constant watching, one could get proper sand at a cost of about $10 a cubic yard; and, by the way, $10 a cubic yard is not a high estimate for rapid-filter sand. At present a winnowing-device is being tried; the first work is satisfactory, and the cost of operation reasonable. It is hoped that the solution of the problem lies along these lines, as separation by hydraulic means is practicable only where water is cheap and abundant.

This paper reflects great credit on its author, his associates, the filter company and all others concerned in the design and construction of this excellent work.

George C. Whipple, Assoc. M. Am. Soc. C. E.—The speaker has been privileged to follow the construction of the Little Falls filter plant from the beginning, and to witness its successful operation. To say simply that it is a success would be faint praise, indeed. It is the first adequate demonstration of the principles of mechanical filtra- Mr. Whipple.

Mr. Whipple. tion applied on a large scale, and its many unique features distinguish it sharply from the conventional type of mechanical filters used heretofore.

Among the features which have interested the speaker especially are those which appertain to the filter proper, namely, the sand, the gravel, the strainer system, and the application of compressed air as an aid in sand washing. These details seem to have been arranged with great care, and, in themselves, are sufficient to render this plant unique.

The fact that so little sand has been lost during the washing process is proof, not only of delicate design, but of careful operation. This fact appeals to the speaker all the more strongly, perhaps, because he has recently had experience with a mechanical filter in which the quality of the sand was poor and the method of sand-washing was imperfect. In this plant the compressed air and wash-water were applied to the bed simultaneously, with the result that in a short period of a few months' time so much fine sand was lost that the effective size increased from about 0.30 to about 0.60. It is certainly more scientific to use sand of a proper size and adjust the wash-water conditions so that no sand may be lost than it is to use a cheap, improperly graded sand and depend upon the wash-water to remove the fine material.

The speaker agrees with those who have already spoken that it is a matter for congratulation that the Little Falls filter has been tested so carefully. While many data are available for experimental plants, there are comparatively few mechanical filters which have been tested adequately. It is only by the publication of such results that the popular prejudices against mechanical filters can be swept away. Take, for instance, the matter of alum. The speaker supposes that there is no engineer who has recommended the installation of a mechanical filter but has had to contend with the popular prejudice against the use of alum, and who has not been told, in cities where such plants have been installed, that the consumers could taste the alum—sometimes even before it was used.

The fact that it is possible to prevent undecomposed alum from passing through a mechanical filter, even though the alkalinity of the original water be low, is demonstrated by the five thousand tests which have been made at Little Falls. This is something to which engineers can "point with pride," and the operators can take as much credit for this as the engineers. Indeed, it cannot be stated too emphatically that the successful operation of a mechanical filter is dependent upon the conscientious and unflagging attention of the operators, night and day, day in and day out. No mechanical filter will run itself. Even automatic devices must be watched. But, while the element of human fallibility is introduced in the operation of a mechanical filter, more, perhaps, than in the case of a sand filter, it must be remembered that locomotives and steam pumps and boilers need to be watched, and so does every form of machinery. It is no more difficult to care for a filter than to care for pumping machinery, and, with the same class of operators and with suitable filters, periods of imperfect filtration ought not to be more common than railroad accidents. Just as the country has developed a class of men skilled in firing boilers and running engines, so there must be developed a class of men skilled in operating filters. At the present time there is no more promising field for a young graduate engineer than that of superintending the operation of filter plants. Such men need to have some knowledge of chemistry and bacteriology—enough for them to carry on certain simple tests of the water before and after filtration—and they should understand the principles of hydraulics and be of a mechanical turn of mind. It is hoped that our engineering schools will take this subject into consideration and see that their students have proper instruction in the operation as well as in the design of filters. Mr. Whipple.

Mr. W. B. Fuller.

WILLIAM B. FULLER, M. Am. Soc. C. E.—As Mr. Hering has well stated, the completion of this plant stands as a milestone marking a distinct progress in the art of mechanical filtration. In a lesser, though still distinctive, way it stands as a milestone from a constructive point of view, in that it has been constructed throughout almost entirely of concrete. This has been done with an idea of making the entire structure as durable and permanent as possible, and it is this part of the work to which the speaker now wishes to refer.

The substructure of the plant, that is, the portions acting as coagulating basins and clear wells, is built as a gravity section of concrete in mass, without iron. The filters over the clear well, the walls of the building proper, and of the monitor, are also built of concrete, with steel rods embedded throughout the mass. All floors and partitions, as well as the benches and chemical hoods in the laboratories, stairways between different levels, mixing, solution and chemical tanks, and columns and girders throughout, are also of concrete construction.

In relation to this construction there are a number of unusual features. The floor over the coagulating basin is designed for a load of 350 lbs. per square foot, and consists of two spans of 24 ft. each, the interior ends of the floor beams resting on concrete girders, resting in their turn on concrete columns from the bottom of the basin 43 ft. deep. These columns average 42 ins. square, and sustain an exterior load of more than 10 tons per square foot. This is possibly as tall a column for sustaining such loads as has yet been constructed of concrete. The floor of this basin, while designed to carry 350 lbs. per square foot, has frequently to carry a loaded cart, the concentrated load on each wheel being about 1 500 lbs.

Mr. W. B. Fuller.

In one portion of the plant there are two mixing tanks, which are 16 ft. in diameter and 16 ft. high, containing about 25 000 galls. of water each. They are round tanks, made of concrete 12 ins. thick, the concrete surrounding an iron skeleton. These tanks are tight and safe with water inside pressing outward or with water outside pressing inward. They are also set upon the top of concrete posts, about 30 ft. above the floor of the coagulating basin.

The stand-pipe, or tank into which the river water and the coagulant first enter, is 10 ft. in diameter and 48 ft. high, and it is tight with a water pressure either inside or outside. It is made of concrete, 15 ins. thick at the bottom and 10 ins. thick at the top, the concrete being reinforced with iron rods embedded therein. This entire tank was built in 8 hours, all the concrete being placed from the top, and thus falling the full depth of 43 ft. when the tank was first started. This is contrary to the ideas of a great many engineers in regard to proper concrete construction, that is, to put in a depth of 43 ft. of concrete continuously without stopping.

This concrete was put in very wet, a wheel-barrow load (5 cu. ft.) at a time, and was merely joggled to position. When the forms were removed the surfaces were absolutely smooth, not a stone or a void showing. It had been intended to plaster the inside surface of this tank to make it water-tight, but the plastering was omitted as being wholly unnecessary.

An interesting part of the construction is the suspending of the steel pipes, 66 ins. in diameter, and full of water, from stirrups fastened to the concrete floor beams.

These pipes when full weigh more than 1 ton per linear foot, and convey the water from the coagulating basin to the filters; for a part of their length they are protected inside with a cement lining.

The filters themselves, of which there are thirty-two, were built under a guaranty as to tightness and strength, the minimum sections of concrete and metal having been specified before bids were received. As these tanks are situated directly above the clear-water basin, it was essential that they should be absolutely water-tight. This result was secured, as a trip around the clear-water basin in a boat failed to detect any dripping from the filled tanks above. This result was secured first by building each tank as a monolith, the bottom, sides, and top, all at one continuous operation. They thus became for all intents and purposes like a nest of boxes, each box being free to move by itself under varying stresses. Each tank was also plastered on the inside first with a ½-in. coat of 1 to 1 cement-and-sand mortar and then a ⅛-in. coat of neat cement mortar. This last coat, below the sand level, was stippled with a stiff corn broom, so as to make the surface very rough, to prevent the passage of water between the sand and concrete sides, rather than through the sand.

Mr. W. B. Fuller.

The concrete in the lower part of the structure was made in the proportions of 1 part cement, 3 parts sand and 7 parts stone, which are rather unusual proportions for water-tight work under heads up to 43 ft. The idea, when the specifications were made, was that it would be best to make a water-tight lining on the inside of the basins with a very rich concrete, and make the outer part of the wall with a poorer concrete, in order to save cost, the theory being that if the inner lining leaked, it would be best to have such water pass out through the back of the wall.

In actual construction, however, it was found that the 1 : 1½ : 3 concrete—the very rich concrete—which was used for the lining, was very difficult to place, and, as placed, it actually was not as tight as the 1 : 3 : 7 concrete. The latter was absolutely water-tight, as far as permeability is concerned. What leaks there are in the plant are very few, and they have always occurred in joints or at cracks due to temperature. A great deal of care was taken in the grading of the sizes of the sand and stone, so as to have the voids filled very thoroughly before any cement was placed in the mass.

Mr. Tribus.

L. L. Tribus, M. Am. Soc. C. E.—It seems that the past has demonstrated that filtration can be effective for the almost absolute removal of sedimentary and deleterious organic matters in public water supplies, and it is also fully evident that many surface-water and some ground-water supplies, as well, will soon have to be filtered.

There can be no question that with proper care either the "rapid" or "mechanical" process, or the "slow" or, as ordinarily described, "sand process," will be effective; one being, however, more of a straining method, the other probably more thoroughly bacteriological, and so, perhaps better, from a strictly sanitary standpoint.

An interesting question, not largely investigated as yet, but to which special attention should be given at an early date, is whether water treated by the "rapid" process will keep longer in storage without spoiling than that treated by the "slow sand process" (the chemicals generally used with the former ought never to be in such excess as to be in themselves a factor). Thus far, it has been deemed most expedient to keep all filtered waters in covered storage reservoirs and in relatively small quantities at that, but as filtration comes into more general use it will be found, in many instances, very desirable to have the processes carried on near the sources of supply, and the filtered water delivered to existing large open reservoirs near the point of use. If all filtered water is going to deteriorate seriously with such "open storage" more rapidly than would unfiltered water, then filtration has not yet reached the point of development which it must reach for universal application. If the same water will keep longer in good condition after being filtered by one of the main processes, then that process will control the general situation.

Mr. Tribus. At the plant under discussion, test analyses of the raw water, the water in the coagulating tank and in the filtered-water basin, have been made systematically, with, perhaps, a few analyses of the water from the tap as delivered some miles away. The results seem to have been eminently satisfactory, but what would the result be if this same water, prior to its use, should be stored for several weeks after filtration, in an open reservoir? The question can only be answered by experiment, and it is to be hoped that such test, along the line suggested, will be made by the company whose plant has been so well designed and so interestingly described by Mr. Fuller.

Mr. Pearse. LANGDON PEARSE, Jun. Am. Soc. C. E. (by letter).—There is one point in Mr. Fuller's admirable paper which is not clear to the writer. He has been unable to find any statement concerning the co-ordination of the rate of application of the alumina sulphate solution to the flow of raw water through the "alum" grid. To vary the application of the alum solution properly, some device is needed. In the writer's brief experience with a small municipal filter plant, a case occurred where the quantity of alum added to the raw water was entirely too small, simply because of the impossibility of measuring the flow of the raw water as it passed the outlet of the alum feed. The alum had to be regulated by the pumpage from the clear-water well, which by no means corresponded to the flow of raw water into the settling basin during the same interval.

Mr. Gregory. JOHN H. GREGORY, Assoc. M. Am. Soc. C. E. (by letter).—Thanks are due, not only to Mr. Fuller for his valuable paper on the Little Falls Purification Works, but also to Mr. J. Waldo Smith, Superintendent and Engineer, and to the other officers of the East Jersey Water Company, for allowing the publication of such a complete description of the plant, and especially of the results accomplished during its first few months of service. The writer knows of no place where so much valuable information requisite for designing a mechanical filter plant properly is available as is given in condensed form in this paper.

The writer visited the construction work several times during its early stages, and was fortunate enough to be located so that he could visit the plant frequently during the latter part of the construction, as well as since it has been put in service, and he has made the most of these opportunities to study the construction and operations in detail. The type of construction adopted at Little Falls is radically different from that used heretofore for mechanical filter plants, and, in the opinion of the writer, is a great improvement over that used for certain other plants built recently. The design of mechanical filter plants in the future will, it is to be hoped, be modeled, in general. closely after the Little Falls work.

The writer is a strong believer in very wet concrete, and it is

Mr. Gregory.

especially interesting to note that the concrete in the main construction at Little Falls was mixed so wet that the workmen had literally to wade through it. Concrete thus mixed requires very little tamping, rather a joggling of the whole mass into position, and the engineer can feel assured that he will get a satisfactory piece of work, and that when the forms are taken down the exposed faces will present a smooth appearance and be free from voids. This smooth appearance was characteristic of the work at Little Falls. Although it is impossible now to inspect very much of the heavy walls, yet certain portions are still exposed, namely, those shown below the superstructure in the views on Plate XVIII,* and a visitor to the plant who is interested in concrete construction will be well repaid by examining these walls carefully. They have not been touched in any way since the forms were first taken down.

It is common practice in filter construction to take certain precautions to prevent the raw water from passing down too rapidly alongside the walls. At Little Falls, as has been stated, the inner walls in the filter tanks below the sand surface were roughened by stippling with a wire brush before the plastering had set. The surface thus produced was very rough, and, in fact, for the end desired, was the most satisfactory surface which the writer has ever seen.

In designing the concrete walls and piers for the slow sand filters at Philadelphia, the writer advocated a slightly different method of procedure. The exposed faces of the piers and walls below the sand line were to be floated with a thin plaster of Portland-cement mortar, and then, before this plaster had set, were to be dashed with sand. The necessary clauses providing for this were inserted in the specifications. After the construction was under way, of course the attempt was made to carry out this provision of the specifications. The writer was not in charge of the construction, but visited the work frequently to watch its progress and the methods used by the contractors. The sanding of the surfaces, as actually done, could hardly be said to be satisfactory, but, in the opinion of the writer, this was due entirely to the method of doing the work. The writer had seen surfaces elsewhere which had been finished rough by being dashed with sand, namely, the coping and exposed faces of small concrete retaining-walls, and surfaces similar to these the writer had in mind when the specifications were written. Recently, he has heard that the attempt to sand these surfaces has been abandoned, and that they are finished smooth, but trusts that he has been misinformed in this particular. In his opinion it would be much better to leave the rather rough surface produced by the common wooden float than to trowel them smooth; or, better still, to roughen them by stippling with a wire brush, as was done at Little Falls.

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* *Proceedings*, Am. Soc. C. E., for February, 1903, p. 171.

Mr. Gregory. The idea of using hydraulic valves instead of the ordinary hand-operated valves was a happy one, and, at a glance, will be apparent to anyone who can watch the daily operations at Little Falls and at other plants. The ease with which the valves are controlled was brought home to the writer very forcibly a few weeks ago. He had occasion to conduct a series of experiments at a mechanical filter plant in which it was necessary to open and close a valve at frequent intervals to control the supply of water. The valve had the ordinary hand-wheel, and it turned very hard, as the stem was bent slightly.

All took turns at handling the valve, and the time and labor consumed was anything but pleasant, to say nothing of the comments which were forthcoming.

The use of air for agitating the sand layer has proved successful. Many times the writer has watched the application of air to the various tanks, in the ordinary operations of washing, when the tanks have been only partly filled with sand, and with no sand when the strainers have been covered with only a few inches of water. When the air is turned on, it naturally finds a relief through the nearest outlets, and the thought passes rapidly through one's mind, "Will it come out all over the bed?" But this is answered at once by the almost instant agitation of the water surface at all points, and, as far as the eye can judge, with a perfectly uniform distribution.

The experiments indicate that at Little Falls the use of air for agitation, in addition to that produced by the wash-water, is of advantage; but it may be that at some other place, with a different water, the air could be dispensed with, reliance being placed on the wash-water alone. Engineers, however, would hesitate to design a plant to operate under such conditions without first having demonstrated its feasibility by a series of carefully conducted experiments.

The Little Falls plant is thoroughly up to date, but experience indicates that here, as with nearly all work, improvements can be made. In the case in question, however, they are entirely of a minor nature, and do not affect the work as a whole.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.

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PAPERS AND DISCUSSIONS.

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DEFLECTIONS OF BEAMS WITH VARIABLE MOMENTS OF INERTIA.

Discussion.*

By Irving P. Church, Assoc. Am. Soc. C. E.

Mr. Church.

Irving P. Church, Assoc. Am. Soc. C. E. (by letter).—The author has presented a derivation of the "Fraenkel Formula,"

$$\triangle = \int_0^l \frac{M m \, d x}{E I}, \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

which seems to the writer to be lacking in rigor; or at least would probably be so considered by a reader not familiar with the books on "Least Work" by Castigliano and Martin, and who, therefore, might be unable to "read between the lines."

For mathematical purposes, an auxiliary force is supposed to be applied to the beam at the point whose deflection is desired, in addition to the actual loading. Now, this force should ultimately be reduced to zero (as in similar demonstrations by Castigliano) before a result can be reached that will be rigorously applicable to the beam under actual loading alone. Such an ultimate reduction to zero is presumably implied by the author in the evident assumption that the effect of the bending moment due to the auxiliary force in the production of the change of length, λ, in fiber, is negligible. Strictly, if M' denote the bending moment due to the auxiliary force alone, we should have

$$\lambda = \frac{(M + M') \, y \, d x}{E I}; \text{ instead of } \frac{M \, y \, d x}{E I}.$$

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* This discussion (of the paper by C. W. Hudson, M. Am. Soc. C. E., printed in *Proceedings* for March, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.

Communications on this subject received prior to June 26th, 1903, will be published subsequently.

Mr. Church. To ignore the M', then, when added to the M (moment due to actual loading), is to anticipate the final reduction to zero of the auxiliary force. But in the demonstration, as presented by the author, the auxiliary force used is one of unity, which, of course, cannot be reduced to zero; and nothing is said as to any change of value on the part of this force.

To the writer, this obscurity seems entirely unnecessary, and he would suggest the following changes in the details of the argument: Let the auxiliary force at the point in question have a value of Q units; and let $\triangle'$ be the deflection, in the direction of this force, of the point of application; as due to the combined action of Q and the actual loading.

Under these circumstances, if M' is the bending moment at any section as due to Q alone, the final stress in any fiber, as due to Q alone, will be $\frac{M'y}{I}$; and hence, eventually, the internal work due to Q alone, in the simultaneous and gradual application of both Q and the actual loading, will be, for the whole beam

$$W = \int_o^l \frac{(M + M')\, M'\, d\,x}{2\,E\,I}; \qquad\qquad (1a)$$

while the external work of Q will be

$$W' = \frac{Q\,\triangle'}{2} \qquad\qquad (2a)$$

Equating these values of W and W', we have

$$\frac{Q\,\triangle'}{2} = \int_o^l \frac{(M + M')\, M'\, d\,x}{2\,E\,I}.$$

If, now, we define a quantity, m, as being the rate at which Q produces the bending moment, M', in any section; in other words, if we state that the value of M' is at the rate of m foot-pounds moment for each pound (or other unit) in the value of Q, we may write $M' = Q\,m$; whence

$$\frac{Q\,\triangle'}{2} = Q \int_o^l \frac{(M + Q\,m)\, m\, d\,x}{2\,E\,I} \qquad\qquad (2b)$$

In this expression it is to be specially noted that m is a function simply of the position of Q (being numerically equal to the bending moment that would be produced at any section by a force of unity at the point in question), but that it is not a function of the magnitude of Q.

Equation 2b may now be written

$$\triangle' = \int_o^l \frac{(M + Q\,m)\, m\, d\,x}{E\,I}, \qquad\qquad (2c)$$

and is evidently available for determining the deflection of the point of application of Q, in direction of Q, as due to both the original load-

Mr. Church. ing and the force Q itself; Q having any value. If, now, Q be made equal to zero, the equation takes the form

$$\triangle = \int_0^l \frac{M\,m\,d\,x}{E\,I}; \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

the quantity, m, retaining its first value, since it is independent of the magnitude of Q, while $\triangle$ denotes the deflection of the point in question, as due to the original loading alone. In this way it would seem that all obscurity in the derivation of the "Fraenkel Formula" might be avoided. It can easily be shown, however, that Equation 2*c* is, after all, nothing more than an expression of the fact or theorem, proved by Castigliano and others, that the deflection or displacement (in the direction of the force) of the point of application of a force, Q, acting with other forces on an elastic beam, is equal to the derivative (or "differential coefficient") of the total internal work of the beam, with respect to the force, Q. For it will be noticed that, if M'' be used to denote the bending moment at any section, as due to all the loads, including Q (that is, let $M'' = M + Q\,m$), we have $\frac{d\,M''}{d\,Q} = m$; and hence Equation 2*c* becomes

$$\triangle' = \int_0^l \frac{M''}{E\,I}\left(\frac{d\,M''}{d\,Q}\right) d\,x \quad \ldots\ldots\ldots\ldots\ldots (2d)$$

Now, the total internal work of flexure for the beam (as far as bending moments are concerned) is known to be

$$W'' = \int_0^l \frac{M''^2\,d\,x}{2\,E\,I};$$

and hence, by Castigliano's Theorem, just mentioned, we have, for the deflection, $\triangle'$, at the point of application of Q,

$$\triangle' = \frac{d\,W''}{d\,Q};$$

that is,

$$\triangle' = \int_0^l \left[2\,M''\frac{d\,M''}{d\,Q}\right]\frac{d\,x}{2\,E\,I}, = \int_0^l \frac{M''}{E\,I}\left(\frac{d\,M''}{d\,Q}\right) d\,x; \quad \ldots\ldots (2e)$$

which is seen to be identical with Equation 2*d*.

It follows, therefore, that the quantity, m, while numerically equal to the bending moment that would be due to a force of unity at the point of application of Q and having the same direction, is simply the derivative of the total bending moment at any section, with respect to Q. As already noted, this derivative is independent of the magnitude of Q (M'' being a linear function of Q), and hence has the same value, when Q becomes zero, as for any other magnitude. It is thus seen that the "Fraenkel Formula" is a particular case of "Castigliano's Theorem."

Mr. Church. While the "Fraenkel Formula" is doubtless the most advantageous for the problems treated in this paper, it may be of interest to call attention to the fact that the "Theorem of Three Moments" (with variable moment of inertia), may be used for the same purpose (if the influence of shear be disregarded), for the reason that in its most general form this theorem relates to any three points in the elastic curve of a bent beam (whether or not there are supports at any of these three points); and that it introduces the deflection of the intervening point below the straight line joining the other two. When the theorem is applied to Problems Nos. 1, 2 and 3, of the paper, the three points chosen would be the two extremities of the beam (over the supports), and the point whose deflection is desired. Under these circumstances, the desired deflection is identical with that which appears in the statement of the theorem, and the end moments are each zero; so that a solution is immediately effected for the deflection. A similar obvious application may be made for Problems Nos. 4 and 5.

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AUTOMATIC MODULES FOR REGULATING THE SPEED OF FILTRATION.

Discussion.*

By JOHN H. GREGORY, ASSOC. M. AM. SOC. C. E.

JOHN H. GREGORY, Assoc. M. Am. Soc. C. E. (by letter).—The author presents a paper on a subject which is of great interest to those who have had occasion to design apparatus for regulating the rate of filtration. Mr. Gregory.

The author states, in the second paragraph:

> "Numerous forms of semi-automatic apparatus of this description have been devised, but as, under the law of the survival of the fittest, they appear to be doomed to speedy extinction," etc.

It is presumed that the author intends to classify under "semi-automatic apparatus" all apparatus which requires hand regulation, and if such is the case, the writer differs decidedly from the statement that such apparatus appears to be doomed to speedy extinction..

The author goes on to state that "at all events, for the purpose in view, it has not been considered expedient to include any special mention of them (semi-automatic apparatus) herein." The author's purpose was to describe automatic modules, as is revealed in the title of the paper, but the writer thinks that it would have been expedient to describe some of the forms of semi-automatic apparatus, point out the defects that may exist, and give reasons for not advocating them.

The author, possibly, is not acquainted with recent American practice in this line; but, if so, he could not have failed to note that in two of the largest and most recent plants, which it is hoped will be

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* This discussion (of the paper by Charles Anthony, Jr., M. Am. Soc. C. E., printed in *Proceedings* for February, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members of the Society for further discussion.

Communications on this subject received prior to June 26th, 1903, will be published subsequently.

Mr. Gregory. placed under construction in the near future, hand regulation has been adopted. The writer refers to the proposed slow sand filters at Pittsburg, the construction of which, unfortunately, seems to be postponed for some little time, and to the filters at Washington, D. C., contracts for which, according to the latest press reports, have just been awarded. While full details of these proposed plants have not been published, sufficient details have appeared in American engineering periodicals, in the last year or so, to show that hand regulation has been the type adopted. The writer knows of one other plant, which has been built during the last year, in which hand regulation is used. In another large plant which is to be built shortly, on the details of which the writer was asked to advise, the unanimous opinion of all concerned was in favor of hand regulation, and the details for the plant have been thus drawn. It would seem from this that, in the United States, hand regulation or semi-automatic apparatus is not doomed to speedy extinction.

The writer has had considerable experience in the last few years in designing apparatus of both automatic and semi-automatic types, and in watching the operations of both, and it may be of interest to point out some of the advantages and disadvantages of each.

While connected with the construction of the Albany filtration plant, designed and built by Allen Hazen, M. Am. Soc. C. E,, he had the opportunity of watching the daily operation of the filters for several months. The apparatus at Albany, as is well known, consists of an orifice, 4 ins. high and 24 ins. long, in a fixed brass plate, situated in a cross-wall in the regulating chamber. The head on the orifice is maintained at a constant level by opening or closing a valve on the main effluent pipe from the filter. Suitable floats, with scales and markers, indicate the rate of filtration on the filter, corresponding to the head on the orifice. The apparatus was designed so that with a head of 1 ft. on the center of the orifice the rate of filtration would be 3 000 000 galls. per acre per 24 hours, and the orifice was placed so that the loss of head could reach a maximum of 4 ft. while still maintaining the head of 1 ft. on the orifice. The filters were designed to run at a normal rate of 3 000 000 galls. per acre per 24 hours, and no difficulty was experienced in throttling the valve on the effluent pipe so that the head on the orifice would be 1.00 ft., or, at the most, 1.01 ft. The variation in rate corresponding to these two heads is only a fraction of 1%, and is so small that it may be neglected.

After a filter is scraped, and when it is put in service, the loss of head is of course small, only a few hundredths of a foot; this increases gradually from day to day, slowly at first, but quite rapidly toward the last end of the run when the filter is clogged. The readings of the loss of head and rate of filtration are taken every few hours, and, if need be, the effluent valve is opened slightly to bring the rate of filtration back to the normal rate desired, as the rate drops off slightly during the period. This dropping off in rate is only a small amount, but, of course, is greater toward the last of the run; in both cases, however, it is not sufficient to affect the quality of the filtrate. Mr. Gregory.

One possible objection to hand regulation in separate regulating houses may be raised, in that the opportunity is afforded the attendant to be negligent in his duties of regularly visiting the filters, and with little chance of detection. The larger the plant, the greater the objection might be; but the writer does not think that it is of sufficient importance to govern the selection of the type of apparatus to be used, except under certain abnormal conditions. He believes that it is as easy to obtain an attendant at a filter plant who will perform his duties faithfully as it is to obtain a watchman, who, in an entirely different kind of plant, will perform other duties faithfully.

If, now, instead of separate regulating houses, a single central regulating house is used, to which the effluent from each filter is piped, especially if the office is in the same building, the possible objection to hand regulation is removed. This latter is an arrangement which the writer has advocated for several years where the general lay-out of the plant is such as to admit of it.

Hand regulation, whether in single regulating houses or in a central one, is advantageous in one respect, in that it requires periodical attendance at each filter, thereby ensuring that any irregularity will not pass long unobserved. With apparatus of the automatic type it is possible, of course, to lengthen materially the period between observations, in fact, with the apparatus set at a given rate to allow it to run until the loss of head is so great that the filter goes out of service. Under this extreme condition, if anything went wrong it would not be known. On the other hand, with satisfactory automatic apparatus, if for any reason the attendance for a short time is omitted, one can feel reasonably assured that things are going along all right. While hand regulation, from its nature, requires periodic attendance, the writer is decidedly of the opinion that automatic apparatus should receive just as careful attention, if the operation of the plant is to be above criticism.

The author makes a very convenient classification of the various automatic modules, and, as would the writer, mentions the floating weir first, that being the type which would first suggest itself. In one of the figures, the author illustrates an apparatus of this type which he calls the Glenfield Jones, in which the discharge is regulated by varying the depth of submergence of the weir; and in commenting on this he states that:

> "This, however, is an imperfect type, as friction causes the weir to be more or less submerged, depending on whether it is floating on rising or falling water, and, furthermore, the adjustment for varying the discharge is cumbersome and inconvenient."

Mr. Gregory. As to whether or not apparatus of this type is imperfect, it would seem to depend almost entirely on the design of the details. If the sliding joint is arranged so that the friction is an appreciable quantity, the apparatus will be more or less imperfect; but experience seems to indicate that the friction at this point can be reduced to such a small amount that it can be neglected. As to whether or not the adjustment for varying the discharge is cumbersome and inconvenient, while it may be so with the apparatus illustrated, it can be said that this also depends entirely on the design of the details. The writer knows that it is possible to construct apparatus of this type so that the adjustment is accomplished in the simplest manner possible, that is, by turning a hand-wheel on an indicator stand.

While considering this subject, it may be of interest to illustrate three sets of apparatus of this type which were designed under the writer's direction for the slow sand filters at Philadelphia. The figures are only drawn in sufficient detail to indicate the general design and operation of the apparatus.

In Fig. 12 is shown the type which was first designed, and which is now in use at the six filters at the Lower Roxborough plant. This consists of a circular copper float, *F*, in the form of a torus, carrying above and secured to it a four-armed cast-iron spider, *Y*, through which is threaded a stem, *S*, at the hub, *A*. On the lower end of the stem, *S*, is carried a smaller four-armed spider, *K*, made of brass, so joined to the stem at *B* that it can turn freely in a horizontal direction, but without any vertical movement on the stem. This spider, *K*, supports a vertical brass pipe, *T*, which, for convenience, may be called the telescopic pipe, the top of which forms a sharp-crested weir, *W*, over which the water flows. This telescopic pipe is enclosed in a cast-iron casing, *C*, the lower end of which connects with the main pipe leading to the filtered-water basin. The telescopic joint, *J*, through which the pipe, *T*, passes, is a brass ring, and is arranged with grooves so that light packing could be inserted if desired. The stem, *S*, is of brass, the lower end only being circular and threaded; above, it is of square brass tubing, and passes up through a circular hole in the floor, which serves to guide the stem. Above the floor is placed an indicator stand with a hand-wheel. The stem passes up through this stand without being connected to it, the hub of the hand-wheel having a square hole through it slightly larger than the stem.

As shown, water is passing over the crest of the weir, thereby giving a certain rate of filtration on the filter. If it is desired to change the rate, this is accomplished by turning the hand-wheel on the indicator stand. By doing so, the stem, *S*, is turned, and, as it is threaded through the spider at *A*, the telescopic pipe, *T*, is raised or lowered with reference to the water level, correspondingly decreasing or

Mr. Gregory.

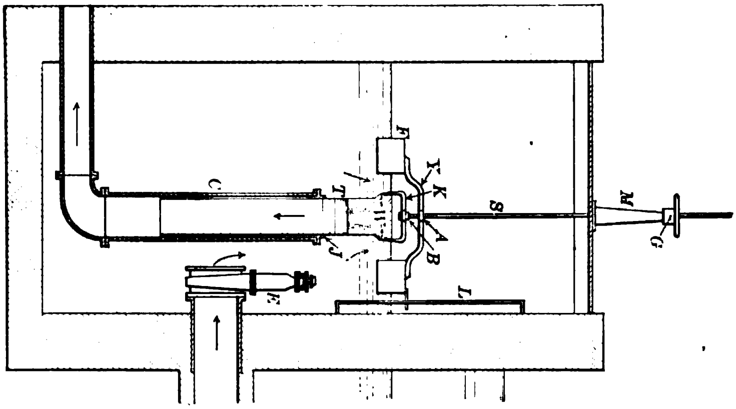

FIG. 12.

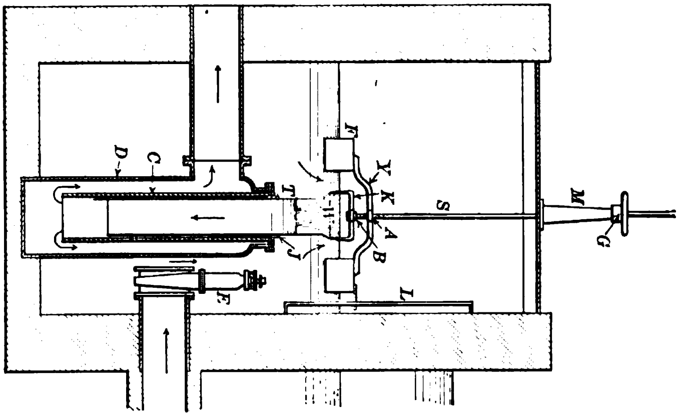

FIG. 13.

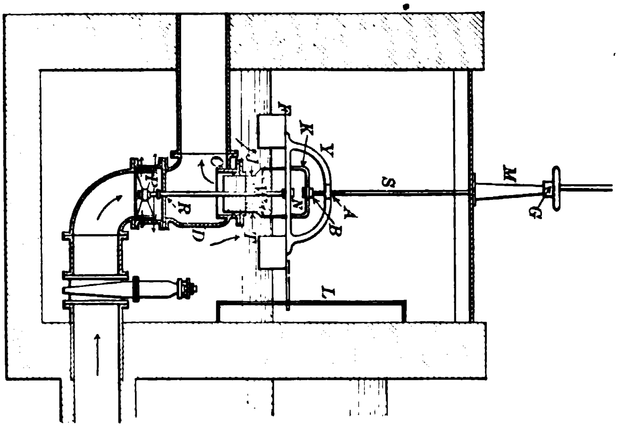

FIG. 14.

Mr. Gregory. increasing the rate. In order that the float, *F*, shall not turn with the stem, a small projecting piece is fastened to it, moving along the guide, *L*, which is fastened to the wall.

The rate of filtration is indicated by a pointer moving over a small horizontal dial at *G*, directly under the hand-wheel. The movement of this pointer is accomplished by means of a brass collar, with a square hole, fitting around the stem, and forming the worm of a train of gearing. The graduation of the dial is determined from experiment rather than from computation.

The weak point in apparatus of this type is, of course, at the joint, *J*. When it came to designing this joint, three styles were considered, one being that shown, another a thin plate with a hole very slightly larger than the telescopic pipe, and the other a cup leather. The writer rather leaned toward the leather joint or the thin plate, but after discussion it was finally decided to adopt the one shown, with the provision, however, that the design should be such that either of the others could be substituted if it was found desirable. It should be remarked that with either of the types which do not make a tight joint at *J*, there will be a certain amount of leakage, greater, of course, at the first of the run when the head is greater; but, in the writer's opinion, this leakage would be so small, compared with the amount passing over the weir, that it would not be a serious matter. This leakage, however, is to be avoided if possible.

After this apparatus was installed it was found that with the joint as designed it did not operate satisfactorily. The writer understands that the cup leather has now been substituted and is giving very satisfactory results.

In designing both sets of apparatus it was intended to provide access for air under the sheet of water, and it was thought that sufficient opening had been provided at the four points where the spider, *K*, was joined to the pipe. It was expected, however, that there would be some entrained air carried along in the solid column of water passing down through the telescopic pipe, due to the agitation at the surface produced by the falling sheet of water. In either event it was not anticipated that it would amount to much. It seems that such, however, was not the case, and that there has been some little trouble caused by air being sucked in. The writer has not had the opportunity of studying the apparatus for any length of time while in operation, and hence cannot suggest what he would consider the best way of remedying it; but, from his knowledge of all the details, several methods have suggested themselves. The trouble with the air in the water passing out through the apparatus, however, does not affect the satisfactory operation of the filter.

When it came to designing the Upper Roxborough and Belmont plants it was found desirable to raise the elevation of the effluent pipe leading from the regulating chambers. This resulted in a modification of the design of the regulating apparatus, which modification is shown in Fig. 13. The upper part of the apparatus is the same as that just described. The change in the lower part is indicated clearly in the drawing. The object in providing the internal casing, *C*, was to prevent a possible cramping of the telescopic pipe, *T*, in the joint, *J*, due to the lateral movement of the water as it passed out into the effluent pipe leading from the chamber. This modified type of apparatus was also included in the designs of the Torresdale plant, to be used for all the filters except one, in which was to be installed a still further modified type. Mr. Gregory.

All the apparatus was designed to run for a maximum rate of filtration of 6 000 000 galls. per acre per 24 hours, and with a maximum loss of head on the filter of 5½ ft. It is readily seen, then, that when the filter is first started after scraping, the water passing over the weir falls several feet, causing the agitation mentioned previously. It should also be noted that during the run the telescopic pipe has a vertical movement corresponding to the total loss of head, and a consequent variation in leakage if a tight joint is not used at *J*, as before stated. It was in an attempt to improve both these features that the apparatus illustrated in Fig. 14 was designed.

The indicator stand, the stem, *S*, the joints, *A*, *B* and *J*, and the float, *F*, are the same as described previously. The spider, *K*, is lengthened vertically, but has no connection with the spider, *Y*, except through the stem, *S*, although the drawing might seem to indicate otherwise. The spider, *Y*, is a double one, the upper part being similar to the one described previously, and serving the same purpose; the lower part carries a vertical valve stem at *N*. The telescopic pipe, *T*, is made much shorter, while the outlet casting, *D*, is quite different in form. Below this outlet casting, *D*, there is a solid plate with an opening at *R* for the valve stem, and below the plate there is a balanced piston-valve, placed on the end of the main effluent from the filter. This valve consists of a hollow internal cylinder or piston, *P*, with openings, surrounded by an annular casing, also with openings. The position of the piston, *P*, is controlled by the float, *F*. The method of changing the rate of filtration, as with the other types, is by changing the level of the crest of the weir, *W*, relative to the water level in the chamber.

The operation of the apparatus may be described as follows: When the filter is started, after scraping, the piston, *P*, will be at its lowest position, with its openings opposite those in the annular casing. The water will pass out through the piston-valve into the chamber, rising up around the float and passing over the weir. When the water has reached a sufficient elevation, the float will rise, carrying with it the piston, *P*, and thereby partly closing the openings in the annular

Mr. Gregory. casing. The float will rise to such a position that the water discharged through the piston-valve will be the same as that passing over the weir, in which position the apparatus will be in equilibrium. The difference in head between the water level on the filter and in the chamber, minus the head lost in passing the filter, will be used up in passing through the piston-valve. At the beginning of a run this head will be several feet, but at the last end will be only a small amount. If at any time the rate is changed, the position of the float and piston will be altered slightly to correspond to the new condition of affairs.

It will be seen, then, that with this type of apparatus the water level in the chamber will remain practically constant, varying at the most only a few inches instead of fluctuating several feet, and thereby giving practically a constant leakage at *J*, if a tight joint is not used. The telescopic pipe, *T*, will have a vertical movement of only a few inches, and its length has been reduced to a minimum. A cup-leather joint, preferably, would be used at *R*, to prevent leakage at this point.

The writer wishes to acknowledge his indebtedness to Mr. L. M. Lloyd and Mr. F. C. Dunlap, his assistants, for several valuable suggestions in working out the details of the three types of apparatus just described.

In conclusion, the writer would add to the two requirements which the author points out should be fulfilled by automatic apparatus, a third, namely, that the loss of head caused by the apparatus should be reduced to a minimum. In the Philadelphia designs it was this requirement which was the determining factor in deciding the use of the floating weir in which the submergence of the weir could be varied.

Vol. XXIX. MAY, 1903. No. 5.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

PAPERS AND DISCUSSIONS.

This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

A SMALL ROCK-FILL DAM.

Discussion.[*]

By Samuel H. Lea, M. Am. Soc. C. E.

Samuel H. Lea, M. Am. Soc. C. E. (by letter).—The writer is unable to see the advantage in hand-packing the up-stream portion of the rock fill. The author states that the object was to help to make the dam water-tight by offering narrow and broken joints which would retain the matter carried in by leakage. This reason would have considerable weight if the up-stream face of the rock fill had been left exposed and free to receive the full volume of silt and suspended matter contained in the water. As the dam was backed with earth on the up-stream side, the only matter that could be carried into the rock fill would be from the earth fill. This fill is stated to consist almost entirely of clay, an impervious material allowing little or no leakage. Mr. Lea.

The writer thinks the hand-packing of the up-stream face of the rock fill rather a disadvantage, except in the respect that the portion thus packed would naturally be of greater solidity and would consequently afford greater stability to the structure. This effect could have been obtained by building the up-stream portion of the rock fill with a slope of 1¼ to 1 and placing the stone without hand-packing. This proceeding would have required an additional quantity of stone, but the cost of the extra stone would have been more than compensated for by the smaller unit cost of the stone in place and by the decrease in the yardage of the earth fill.

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[*] This discussion (of the paper by H. de B. Parsons, M. Am. Soc. C. E., printed in *Proceedings* for March, 1903), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

Communications on this subject received prior to June 26th, 1903, will be published subsequently.

Mr. Lea. As constructed, the rock fill and the earth fill meet in a comparatively smooth surface, affording no chance for a bond or connection between the two substances. This surface constitutes, in effect, a plane of weakness, which is likely to become a sliding plane if stormwater or flood-water uses it as a channel or duct. Should this occur, the displacement of parts of the earth filling nearest the rock might follow, and this would cause settlement in the earth fill. If the slope suggested by the writer—1½ to 1—had been used, and the earth nearest the rock had been well tamped into the interstices between the stones and the irregularities of the surface, a good bond would have been formed between the earth and rock fills and the liability to slip thereby lessened. In addition, the danger of the penetration of stormwater or flood-water would have been minimized.

If preferred to have the up-stream face of the rock fill hand-packed, it would have been better to have finished it in steps. The earth filling next to the stone could have been selected clay carefully tamped. A good bond would thus have been formed. The author does not state whether the cut-off trench was connected with the dam in any manner to prevent seepage over the top of the sheet-piling. To insure water-tightness the trench should have been filled with clay well puddled, and the filling carried up over the face of the rock fill for a foot or more, joining the clay filling next to the rock fill.

In large rock-fill dams, constructed in the West, provision is generally made for water-tightness by special constructions, such as timber facing, steel diaphragms coated with asphalt, or by other methods.

The writer believes that the methods suggested by him will meet all requirements in the case of a small dam such as that under consideration.

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NOTE ON THE COEFFICIENT OF ELASTICITY OF CONCRETE AND MORTAR BEAMS DURING FLEXURE.

Discussion.*

By W. K. Hatt, Assoc. M. Am. Soc. C. E.

W. K. Hatt, Assoc. M. Am. Soc. C. E. (by letter).—The coefficient of elasticity used ordinarily by the designer of steel-concrete beams is that for direct tension or compression. It does not seem that the moduli given by Mr. Falk are of value for this purpose. Mr. Hatt.

Assuming, however, that the results desired by the author are useful, it appears that the details of the method of measuring deflections by means of a lever deflectometer should have been related. If this lever was placed directly under the beam, the amount of compression at the supports must have influenced the character of the curves shown in Fig. 1. Especially, in the case of the shorter beams, is it true that the deflections are probably due to compression at the support, shear of the beam, and bending of the beam. The ratio of height to span of only 1 to 4 in the case of the half beams is too small to yield proper values of the coefficient of elasticity in bending.

The author does not describe the method of calculation used to determine the coefficient of elasticity and the extreme fiber stress quoted in Table No. 1. If these are the result of the application of a formula that is based upon an assumption of a rectilinear relation between stress and strain and of equal moduli in tension and compression, it is the writer's opinion that the results of such computations are of little significance.

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* Continued from April, 1903, *Proceedings*. See February, 1903, *Proceedings* for paper on this subject by Myron S. Falk, Jun. Am. Soc. C. E.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
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PAPERS AND DISCUSSIONS.

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THE PRESERVATION OF MATERIALS OF CONSTRUCTION.

An Informal Discussion.*

By Messrs. James Forgie, William R. Webster, Horace J. Howe, Theodore Belzner and William W. Crehore.

Mr. Forgie. **James Forgie**, M. Inst. C. E. (by letter).—Quite recently, and incidentally, the writer mentioned to Mr. Noble that he had a piece of iron, about 200 years old, in the form of a masonry cramp or bonding iron, approximately ⅜ x ¾ x 6½ ins., with the addition of the ends turned down (Fig. 2), and which he thought might be worthy of testing, both physically and chemically.

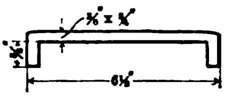

Fig. 2.

Mr. C. L. Harrison has suggested that, in view of the discussion on "The Preservation of Materials of Construction," a note of the history of this piece of iron might be presented, and, probably, in view of the gigantic iron-framed buildings, where the iron is largely inaccessible for painting, it may be of all the more interest to American engineers.

In 1899, while acting for Sir Benjamin Baker and Messrs. Hay and Mott as Chief Assistant Engineer on the City and South London Deep Underground Railways, the writer found this piece of iron within the sandstone masonry of one of four piers forming the pedestals of four triple sets of stone Corinthian columns which were being underpinned to steel girders, in the process of forming a railroad depot in the crypt or vaults of St. Mary Woolnoth Church, at the junction of Lombard and King William Streets, facing the Bank of England, in London, England.

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* Continued from the *Proceedings* for March, 1903.

PLATE XLII.
PAPERS, AM. SOC. C. E.
MAY, 1903.
FORGIE ON PRESERVATION OF
MATERIALS OF CONSTRUCTION.

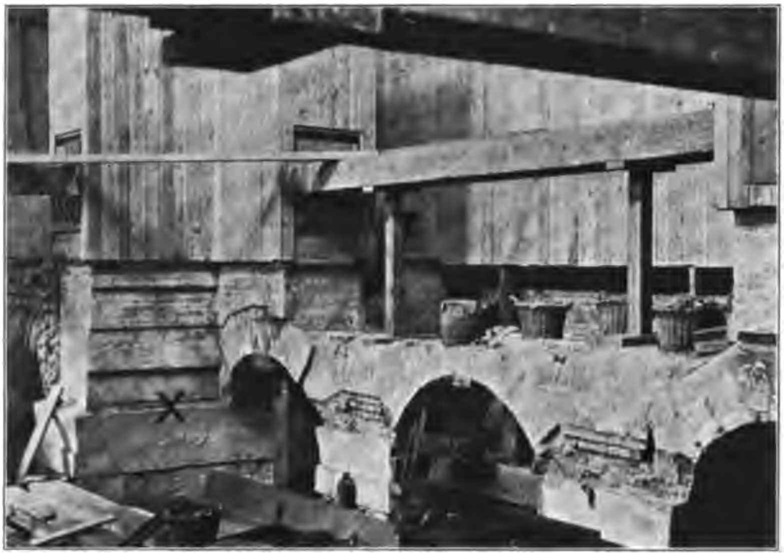

Fig. 1.—Partially Demolished Crypt of St. Mary Woolnoth Church. The Cross Indicates the Place from Which the Iron Cramp was Taken.

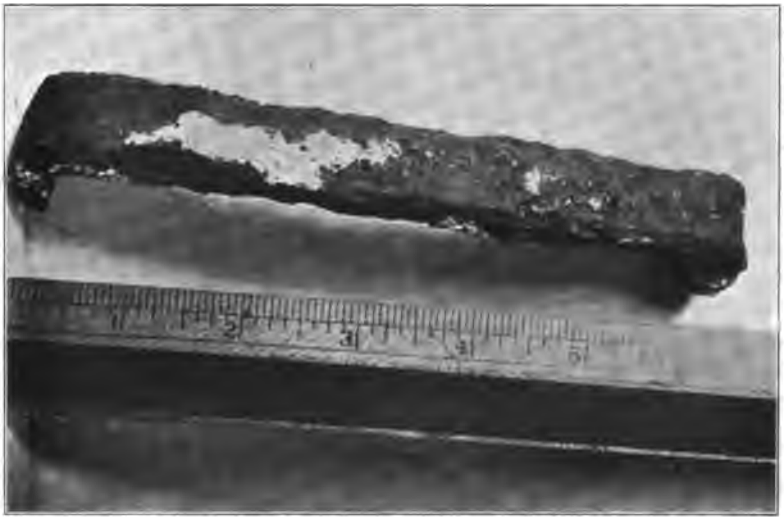

Fig. 2.—Iron Cramp Taken from Masonry in Crypt of St. Mary Woolnoth Church, London, England.

Mr. Forgie.

From this pier also radiated the vaulting or arch groining forming the floor of the church and the roof of the crypt, where, also, several human bodies were found encased in complete lead-shell coffins embedded in the foundations.

This church was built on the site of a church destroyed previously by the great fire of London in 1666, and was designed by Nicholas Hawksmoor, a pupil, and eventually a contemporary, of Sir Christopher Wren.

The iron cramp or bond was wholly embedded in a horizontal sandstone masonry joint made of lime (a hydraulic and not a pure lime).

It may be observed that practically no oxidation can be discerned by the microscope. Attention is also drawn to the pieces of lime still clinging to the iron.

It may be that the lime has acted as a preservative, and, *a propos* of this, the writer may be permitted to observe that in 1895 a piece, about 12 ins. square, of the cast-iron shell of the Tower Subway under the Thames, built in 1869–70, was cut out for the inspection of the Arbitrator in the City of London *versus* the Subway Company. The writer saw this piece immediately after it was cut out, and, on removing the shell of lias (hydraulic) lime grout from the iron, the thin coating of coal tar, which still remained on the iron, smelt perfectly fresh, and the iron was in perfect condition. Within the past six or seven years the writer has removed several hundred feet of other cast-iron tunnels in the process of enlarging the Subway. These had been in place from ten to twelve years, and the iron was also found to be in a perfect state of preservation. The soil in which these tunnels are built is a stiff blue moist clay.

On account of the strong belief in hydraulic lime and Portland cement as a preservative of iron, all the 400 to 500 tons of steel columns and girders which now carry the afore-mentioned church, over the railway depot, were covered with expanded metal and then wholly encased in neat Portland cement.

Fig. 1, Plate XLII, is a photograph, of the partially demolished vaulting of the church, on which the place from which the iron cramp was taken is indicated by a cross. Fig. 2, Plate XLII, is a photograph of the cramp.

Mr. Webster.

William R. Webster, M. Am. Soc. C. E. (by letter).—The small iron cramp referred to by Mr. Forgie, which was subsequently sent to the writer for test, seems to have been originally ¾ × ⅜ in., one end thickened in bending and the other end considerably wasted away.

Before testing the cramp the ends were sawn off, leaving them in their original condition. The material was very hard in spots, and three hack-saws were dulled in cutting off the ends. The body of the cramp was cleaned of all scale and mortar by light blows of a hammer. It was rusted badly in some places under the adhering mortar. In order to grip it in the testing machine it had to be reduced in thick-

Mr. Webster. ness, and on pulling developed a bad seam, otherwise the ultimate strength would, no doubt, have been somewhat higher. The following are the results obtained:

Area.	Ultimate strength.	Percentage of elongation in 2 ins.	Percentage of reduction.
0.104 in............................	51 296 lbs.	18.00	35.8

Analysis.—Carbon, 0.008%; sulphur, 0.027%; phosphorus, 0.060 per cent.

The writer is indebted to Mr. R. Job, Chemist of the Philadelphia and Reading Railroad Company, for the chemical determinations.

Mr. Belzner. THEODORE BELZNER, Jun. Am. Soc. C. E. (by letter).—Regarding the steel beams taken out of the sidewalk vault, mentioned by Mr. William Barclay Parsons,* the writer would like to know whether, from Mr. Parsons' observations, these beams had received a shop coat of oil.

Steel, embedded in concrete, such as grillage beams, etc., should be cleaned thoroughly. The writer does not think it necessary to have them painted; but, of course, this does not apply to steel which is partially embedded in concrete, such as the side columns, roof beams and girders having exposed surfaces, now being used in the construction of the New York Rapid Transit Subway. Steel which is partially embedded in concrete should be cleaned thoroughly, either by the sandblast process or by brush and scraper, and then given a good priming coat of red lead, to be followed by a protective coat of some standard carbon paint.

Mr. Howe. HORACE J. HOWE, M. Am. Soc. C. E. (by letter).—Reference might profitably be made, it seems to the writer, to the remains of the habitations of the Ancient Lake Dwellers of Switzerland, as furnishing the best authentic instances of the preservation of wood and other substances under the most favorable conditions, from pre-historic times (in fact, from the New Stone and Copper Ages) up to the present time.

The building up of the habits and customs of that period, by means of somewhat advanced Sherlock Holmes methods, is very interesting, but hardly calls for more than a mention here.

In the winter of 1853-54, the waters of Lake Zurich fell to a remarkably low level, thereby revealing certain piles in the bottom, at no great distance off shore. These piles proved to be from 15 to 30 ft. in length and from 3 to 9 ins. in diameter. They were in rows, sometimes parallel to the shore, sometimes at right angles to it, and were either firmly embedded in the mud or supported by heaps of stones at the base. Sometimes they were driven through boards which rested on the bottom. Mr. Howe.

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* *Proceedings*, Am. Soc. C. E., for March, 1903, p. 307.

The piles were braced together by means of transverse beams with wooden-pin connections, and planked over so as to form a platform on which the huts were built.

There was also a draw-bridge connection with the shore.

Few piles now project more than 2 ft. from the bottom. They are saturated so thoroughly with water that they are quite soft. Some of them appear like needles, which elsewhere have disappeared and left only a black disc. This is true, however, principally of the oldest, those of the Neolithic Age.

The point which entered into the mud still bears the marks of the fire and of the stone hatchets, or later on, of the metal hatchets. The manner of driving to so great a depth into the ground is difficult to imagine.

As to the various objects which give the key to the doings of this people, Sir John Lubbock says :*

> "Lying among the piles are fragments of bone, horn, pottery and sometimes objects of bronze. Most of them are imbedded in the mud or hidden under the stones, but others lie on the bottom, yet uninjured; so that when, for the first time, I saw them through the transparent water, a momentary feeling of doubt as to their age rose in my mind. * * * The upper parts of the objects also, which are bathed by the water, are generally covered by a layer of carbonate of lime, while the lower part, which has sunk into the mud, is quite unaltered."

In many other Swiss lakes, habitations are indicated in like manner, and it is understood that the Swiss archæologists have made the most of a golden opportunity. The Antiquarian Society of Zurich—Keller and others—was one of the first to do so; and it is quite possible that an official correspondence with that society would be productive of results as to the present status of the entire subject.

Mr. Crehore. WILLIAM W. CREHORE, M. Am. Soc. C. E. (by letter).—In the previous discussion of this subject one point concerning the protection of metals by paint seems to have been entirely lost sight of. When the first coat of paint is applied to the bare metal, the action is somewhat analogous to that which accompanies the application of the priming coat to a piece of soft pine; the oil soaks into the "pores" of the metal and carries the pigment with it. In cast iron the action is discernible to the naked eye, but it takes place also in steel, although to a less extent, on account of the greater density and, consequently, the less porosity of the latter.

Obviously, the oil in a paint is the conveyer, or the medium by which the pigment is brought in contact with the metal. The oil is,

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* "Pre-Historic Times."

Mr. Crehore. also, to a certain extent, a protector of the metal when it is itself protected by the pigment. Pure oil, by itself, unmixed with a pigment, will protect the metal as long as it lasts, but it very soon evaporates and is gone. In the mixture the oil which is outside, next the air, soon evaporates and leaves the pigment, while the oil which is inside, next the metal, remains there permanently because of the protection afforded by the outside pigment. In order to protect the coating next the metal more thoroughly, therefore, a second coat of paint should be applied as soon as possible after the first one is dry.

In view of this combined action of the oil and the pigment it follows that the further the pigment can be injected or carried into the pores of the metal, the better is the bond between the paint and the metal; and if the pigment itself is a good protector its efficiency is certainly increased rather than diminished by being well bonded. Owing to the great density of steel or iron, this action is very slight, in comparision with the absorptive power of wood, and its amount depends upon the fineness of the pigment, as well as upon the density of the metal. This is one reason why paints differ in efficiency as protectors of metal. The more finely ground pigment makes the better metal paint, other things being equal, and such a pigment is conveyed better by a thin oil than by any other. Then, too, the quantity of oil in the mixture is an important point, as well as the degree of completeness with which the oil and the pigment have been mixed together. The requirements, therefore, for a good metal paint are somewhat analogous to those for a good concrete. As, for the latter, there should be just enough cement to fill the interstices between and to cover completely each particle of sand, and just enough of the mixture to fill the interstices in the stone; so, for the former, the pigment should be ground fine enough to enter the pores of the metal, the oil should be of correct quantity, so that it is thoroughly filled or loaded with the pigment, and thin enough so that it will carry the pigment into the pores of the metal. It seems, then, that to produce the ideal metal paint requires: (1) that the pigment should be a good protector, (2) that the pigment should be very finely ground, (3) that the oil should be pure and very thin, (4) that there should be just enough and not too much oil in the mixture, (5) that the two should be completely mixed together.

Furthermore, to obtain the best results, such a paint must be applied next the bare metal itself, without any intermediate coating of oil or scales of rust, either of which obstructions will prevent the pigment from reaching the pores of the metal. The writer contends that the metal should be absolutely bright and clean before being painted. The fact, referred to by Mr. Seaman, that the first coat of paint will adhere better to metal with a dull surface than to metal with a bright surface is because the dull surface possesses the greater porosity of the two and consequently affords a better opportunity for bonding the paint. Experience, however, shows that to check rust which has once begun is impossible, but that it keeps on increasing even though covered with a good paint. In view of this fact it is best to have the metal cleaned by sand-blast, before being painted, in order to insure the best results, with any paint. Mr. Crehore.

The action of the cement in a concrete covering for metal work is practically the same as that of a good paint. The cement will adhere better to the metal if there be nothing between it and the bare surface of the metal; and the concrete forms fully as good protection, under ordinary conditions, as would a good paint. If, however, the metal is located where there is occasional moisture, ordinary concrete is not a sufficient protection, and in such a case the metal should be painted before being set. On the other hand, if the concrete and the steel are expected to act together to resist stress in combination, a coat of paint prevents bonding between the metal and the concrete, and then it should not be used.

That we have not sufficient data to establish indisputably the superiority of those paints which approach more nearly than others to the conditions above mentioned, is chiefly because this subject has never been handled scientifically. Most of our observations are general, or are made under different conditions, and nearly all the available data have been compiled by men who were biased or prejudiced by a personal interest in one or another party to the competition. Comparisons to determine the relative efficiencies of different paints should be made by an absolutely disinterested commission, and under sufficiently varied conditions to establish superiority in one or another of the points now in dispute; such points, for instance, as whether the pigment or the oil is the more important element in the durability and efficiency of paint; what substances make good pigments and what substances are absolutely without merit as pigments; what the comparative effect would be of deleterious chemical fumes on the pigments of different paints; whether a given paint is less efficient when put on with a spray than when rubbed in with a brush, etc., etc. The report of such a commission need not favor any one paint exclusively, but it should define thoroughly the principles on which the composition of a good paint is based, and it could divide all who entered the competition into classes or groups graded according to relative merit in certain important features of the examination.

The writer believes that several of the manufacturers of paint would not only enter their products for comparative examination and exhaustive tests, but also would be glad to share the necessary expense of such work, provided they were assured of the absolute fairness and impartiality of the tribunal and its ability to handle the subject in a spirit of practical and scientific research. A Special

Mr. Crehore. Committee appointed by this Society ought to carry the weight necessary to make its results of great value, and to induce those manufacturers who have any confidence in their products to enter the race voluntarily. Most engineers are in great need of some authoritative information on this subject, aside from the variety of conflicting data and theories gratuitously furnished by paint manufacturers, and cannot afford either the time or expense to investigate it individually.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the Volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

ROBERT BLUM OLNEY,* Assoc. M. Am. Soc. C. E.

DIED MARCH 4TH, 1903.

Robert Blum Olney was born on September 20th, 1870, at Charleston, South Carolina. He was the son of Clarence C. and Louisa C. Olney, of Charleston.

From January to August, 1888, he was employed in the office of the Chief Engineer for the Savannah, Florida and Western Railroad (Plant System), and from September, 1888, to June, 1892, he attended Lehigh University, from which he was graduated as a Civil Engineer in June, 1892. At college he was painstaking, and always reliable and trustworthy in his work, and his scholarship was excellent. Professor Merriman states: "His thesis was entitled, 'Plans and Specifications for a Locomotive Round House,' I find the drawings made with great neatness and the subject well treated throughout."

After graduation he was engaged on the Ohio Extension of the Norfolk and Western Railroad, in work varying from reconnaissance to final estimate, locating, re-tracing and revising lines, construction and track laying. In 1893 he was employed making surveys in the Powhattan mines of the Pocahontas coal field. From January, 1894, to January, 1898, he held the position of Assistant City Engineer of Charleston, South Carolina. His work consisted of general municipal engineering and public improvements, pavements, drainage, etc., and the reconstruction of the sea wall at the Battery. He was also Principal Assistant Engineer on the construction of the separate system of sewers—the sewage being lifted by Shone ejectors. From May, 1895, to May 31st, 1901, he was Engineer and Superintendent in charge of the sewers, power-house and other details connected with the sewer plant.

In June, 1901, by leave of the Mayor of Charleston, at the request of The American Pipe Manufacturing Company, he resigned his position in charge of the Charleston sewerage works and accepted a position with the latter company. In that capacity, he made topographic and hydrographic surveys for the location of a projected new water supply on Goose Creek at Charleston, South Carolina. During the summer he was engaged on the plans for the new Charleston Water-Works, and in the fall of 1901 he made extensive topographic sur-

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[*] Memoir prepared by J. W. Ledoux, M. Am. Soc. C. E.

veys in Westchester County, New York, connected with water-works systems controlled by The American Pipe Manufacturing Company. In the spring of 1902 he was placed in charge of construction of the separate system of sewerage and the disposal plant for Burlington, New Jersey, the contractors being The National Gas and Construction Company, allied to the American Pipe Manufacturing Company, the sub-contractor being George Pfeiffer, Jr., of Camden, New Jersey.

After the completion of this work he was placed in charge of the construction of Charleston's new water supply from Goose Creek, but, on account of his failing health, remained there but a short time. He then left for the Southwest, intending to locate in a favorable climate in New Mexico or Arizona, but stopped at San Antonio, Texas, where he died on March 4th, 1903. It is stated that he was walking on the streets, apparently in fair health, on the day of his death. His remains were brought from San Antonio to Charleston, South Carolina, his home, and placed in the family plot in the beautiful Magnolia Cemetery.

Mr. Olney was especially capable in his professional work. He was a man of high integrity, and had the respect of all who knew him. The first intimation of his failing health occurred in the winter of 1901–1902 when a New York physician, whom he consulted in reference to some slight ailment, told him that he had symptoms of tuberculosis. This appeared to prey on his mind, although, even up to the last, his health gave no evidence of breaking down.

Mr. Olney was elected a Junior of the American Society of Civil Engineers on January 3d, 1895; and an Associate Member on September 5th, 1900.

WATSON WELLMAN RICH,* M. Am. Soc. C. E.

DIED JANUARY 12TH, 1903.

Watson Wellman Rich was born at Dayton, New York, on March 9th, 1841.

During the past generation he was the best known civil engineer in the Northwest. He spent the major portion of his professional life in the country between the Great Lakes and the Dakota Plains, of which the twin cities of St. Paul and Minneapolis form the commercial center. He was prominent during the three most teeming decades of the marvelous growth and development of this Northwest, through his connection with three of its railroads. He had direct and responsible charge of the construction of some two thousand miles of railroad over that portion of our country.

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* Memoir prepared by Samuel B. Fisher, Esq.

Going to the northwest portion of Wisconsin shortly after the Civil War, from which he was discharged as Captain of Volunteers (having refused the command of a colored regiment because he deemed it inconsistent with the high sense of honor held in choice army circles to enter that branch of the service), with previous liberal education, after having spent about two years in the service of various railroads and of the United States Engineer Department as Assistant Engineer, he became identified with the Wisconsin Central Railroad in July, 1870. During the next eight years he was busily engaged in constructing and operating this railroad, through the then almost unbroken forests, over the deep ravines and steep slopes of that difficult country, the south water-shed of Lake Superior, and often in half conflict with its then rough inhabitants.

From 1879 to 1883 he was Chief Engineer of the Minneapolis and St. Louis Railway, building five or six hundred miles of road in Minnesota and Iowa.

All his life he was consulted about, and frequently examined and reported on, enterprises. In this respect he occupied the highest position in the Northwest.

From 1883 to 1890 he was building the principal monument of his career in the construction of the Soo Line, extending from Minneapolis eastward, entirely across the timbered States of Wisconsin and Michigan to Sault Ste. Marie, and westward almost as far as the Dakota Plains. After building the Soo Line his health was not very good, for a couple of years, although he did a considerable amount of miscellaneous work. In 1892 he resumed construction on the Soo Line, putting through its Northwest extension to the International Boundary.

Mr. Rich was most expert and proficient in the use of wood in structures, especially in bridges. His designs and plans for Howe trusses were perhaps the best that have ever been used.

In 1897, ripe in age, rich in engineering experience, strong in character, he went to China. He went first with ex-Senator Washburn to examine the route of the proposed Hankow Railroad for the Brice syndicate. Arriving in China, the Government would not even let him look at it. After some time, however, the Government called for him and delegated him to examine the line, not for the syndicate, but for the Government. On this trip he was accompanied by about a regiment of men, proclamations were sent in advance, calls were made on the Viceroys, etc. There was great difficulty in infusing into the lethargic heels of this superfluous multitude an acceleration of movement proportional to a reconnoissance of six hundred miles of line within a specified time. Early in the progress of this reconnoissance he gave the leader and officer in charge of these auxiliary forces a very practical object lesson, as shown by the following incident related by himself: Proclamations had been sent ahead to hold a feast at a certain important town, which would have required going into camp about 2 P. M. Mr. Rich, deeming this incompatible with finishing the reconnoissance within the time agreed on with the Government, pushed on with his work, going into camp miles in advance. As the convoy had orders to let no harm befall him, they feared the consequences of disobedience, and came straggling into camp at all hours during the night. There was no further serious difficulty about delays, and this reconnoissance of six hundred miles, on the route which will in all probability be the principal trunk line of China, was completed on time. After having his report translated into Chinese he returned to America, only to go back again in a few months as Consulting Engineer for the Chinese Government, his field being the southern part of the great Chinese Empire. He soon buckled into work, and was engaged in building a coal road a thousand miles in the interior, with the use of Chinese labor and facilities, among which was making embankments with material carried in baskets on the backs of natives, when the Boxer uprising stopped the work.

Actual operations began again soon after the Boxers were suppressed, Mr. Rich's engineers being among the first to return to work. Although he did not again go to the far interior, because His Excellency Sheng required his presence and services in Shanghai, the interior coal road is nearing completion, having been continued in charge of S. L. McCalla, immediately under Mr. Rich's directions.

Since July, 1902, Mr. Rich was a moving spirit in that American enterprise, the Hankow-Canton Railway. In December, 1902, he was appointed Chief Engineer of Construction, of that company. Engrossed in these large affairs, he spent his vital energies in the midst of the novel problems connected with it, and although sustained to the last by his strong will, he died on January 13th, 1903, in Shanghai, which was then his home.

During his intercourse with the ruling and merchant classes of the Chinese he formed a very great admiration for the integrity and other sterling qualities shown in their character, as well as a distrust of the tricky Japanese. In a marked degree, the Chinese gentlemen who knew him confided in him and expressed profound sorrow at his leaving this sphere of existence. Had he lived and remained in the Orient he would have been a strong force in remoulding, or at least modifying, the Chinese character, and conforming its enterprises, to as great an extent as that would have been possible, to lines of modern thought and action.

He was a most masterful man. "His backbone—as he himself expressed it one day—came up into his hat." His friends all know that his heart was bigger than his backbone. He was every inch a gentleman. Like all strong characters, he was forceful in his dislikes and in his few enmities, as well as in his friendships. With his ever welling-up sense of humor and his genial disposition, he was the most delightful of companions.

Connected all his life with projects for the development of the country, in which large fortunes were made, he never tried to reap personal enrichment from them, but devoted all his time and energy to the interests of his employers. He died a man of small financial means, but rich in good will toward his fellows. He was never known to be envious, but always expressed the most unfeigned satisfaction at the success of his friends. His assistants and subordinates who were brought into close contact with his personality imbibed and ever after maintained feelings of trust and loyalty toward him. His good disposition toward others was contagious. All over the country are men, formerly associated with him, who bear in their hearts the salt of good intentions, infused into them from his ingenuous nature. Dominating all his other qualities, was a regal and ever-present sense of honor.

He was first a well-rounded man, in possession of all his faculties, and afterward a civil engineer. He might have followed almost any other avocation successfully had he devoted his capacity to it. While his work in America was, in a sense, completed, his departure leaves a void in the circles of his friends and engineering associates which can never be filled. It may be truthfully said of him, as it was said of one of old: "Know ye not that there is a prince and a great man fallen this day in Israel."

Mr. Rich was elected a Member of the American Society of Civil Engineers on September 5th, 1883.